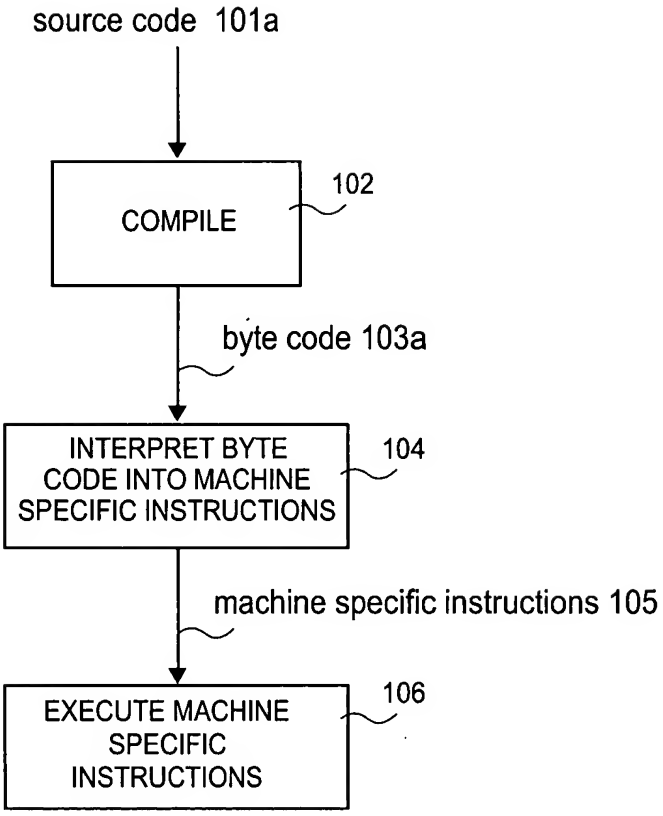


FIG. 1A
(PRIOR ART)

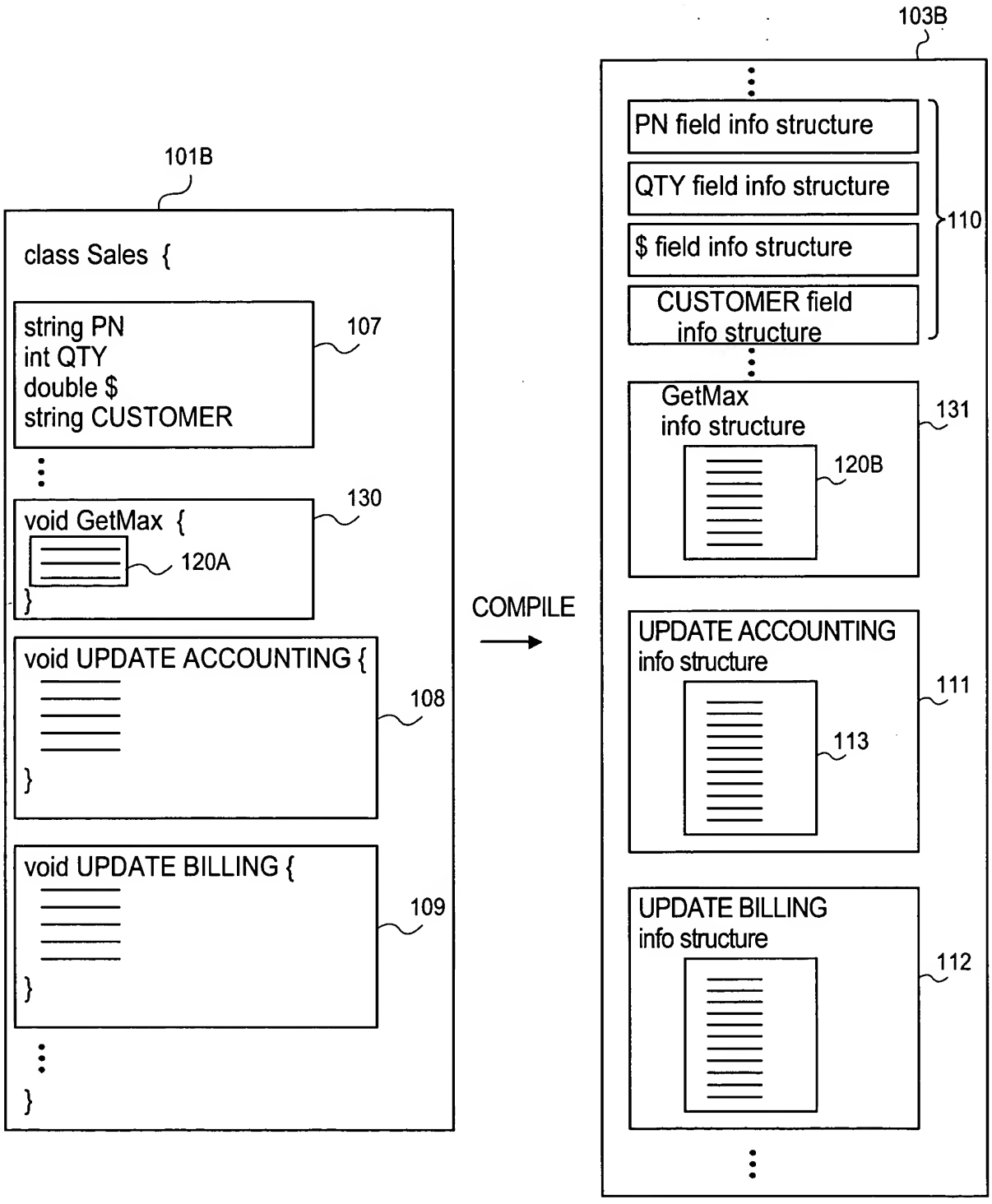


FIG. 1B
(PRIOR ART)

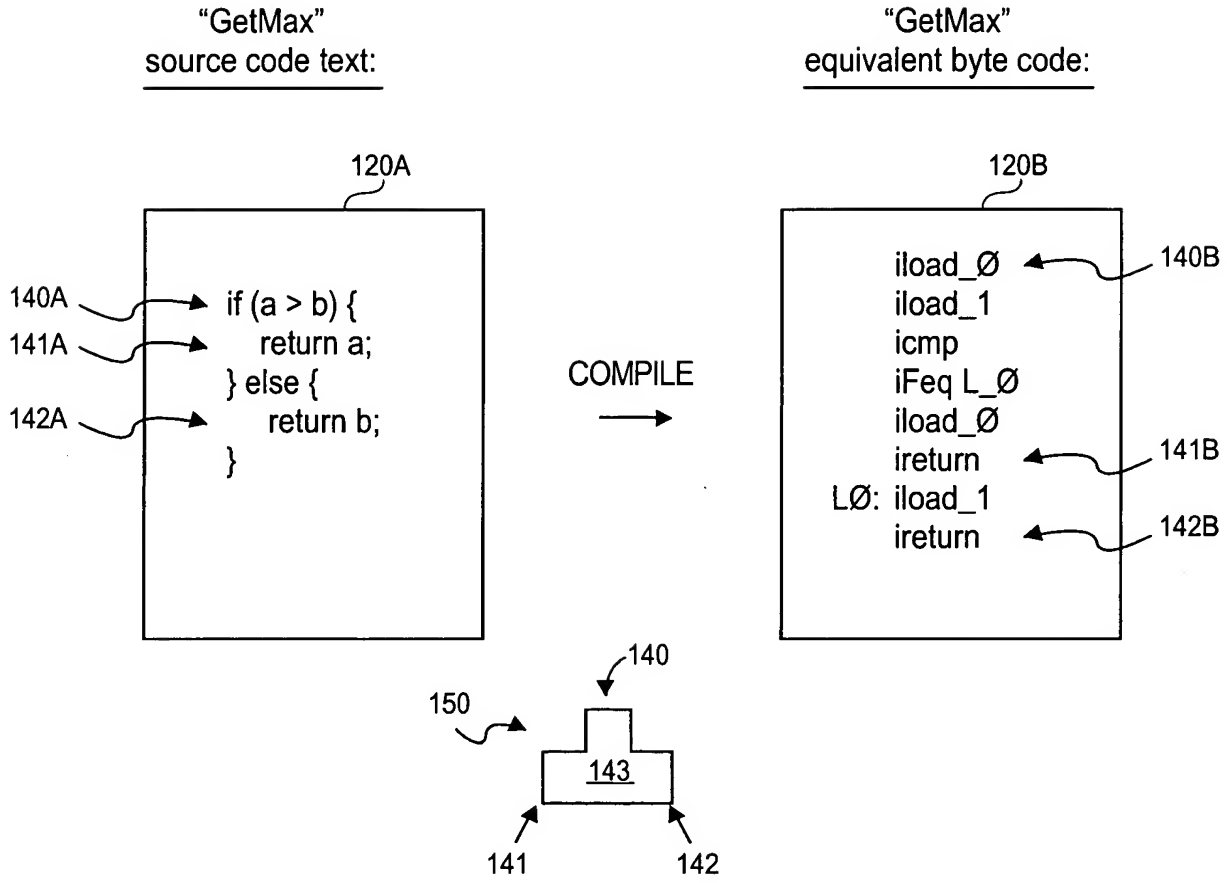


FIG. 1C
(PRIOR ART)

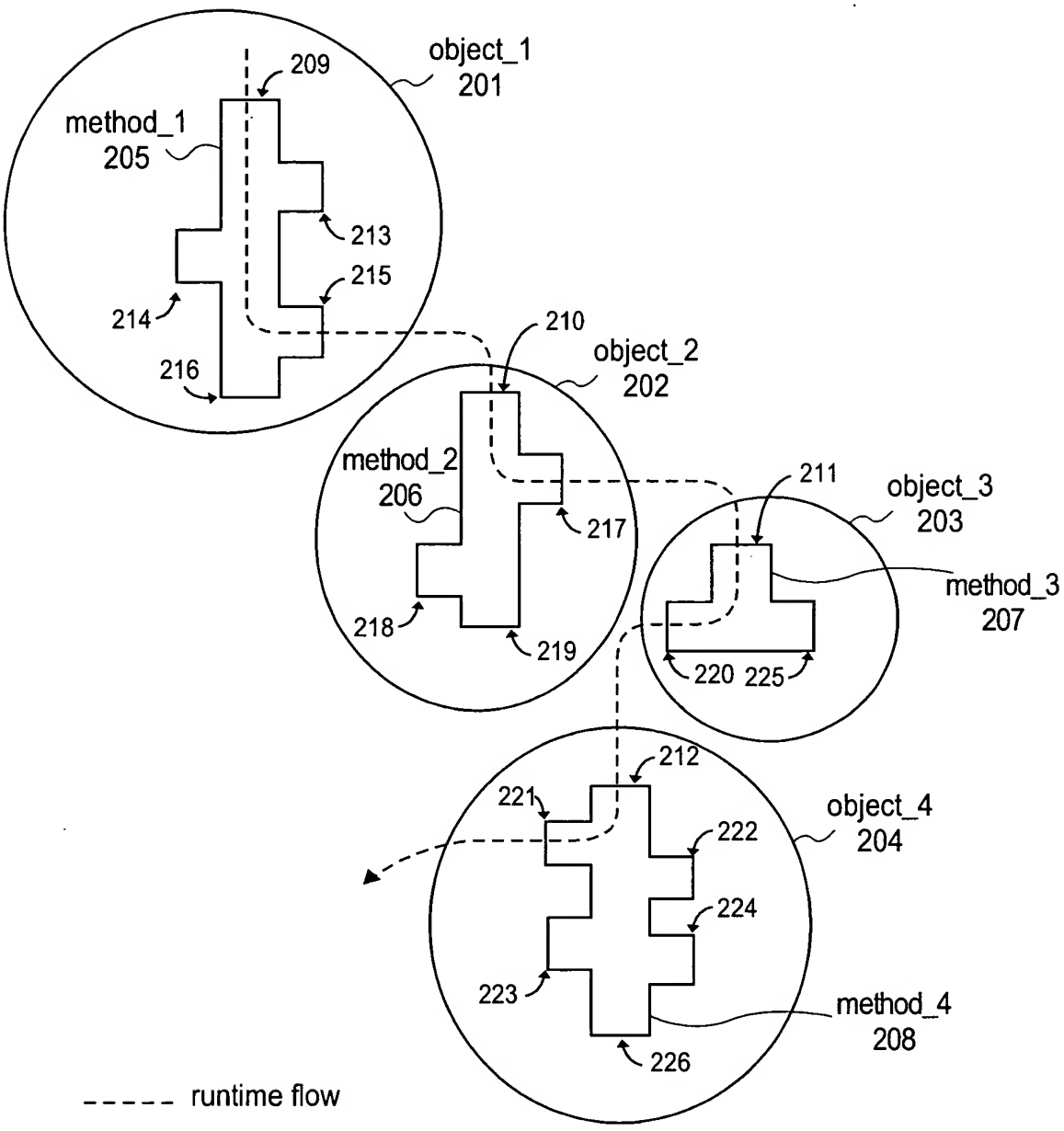


FIG. 1D
(PRIOR ART)

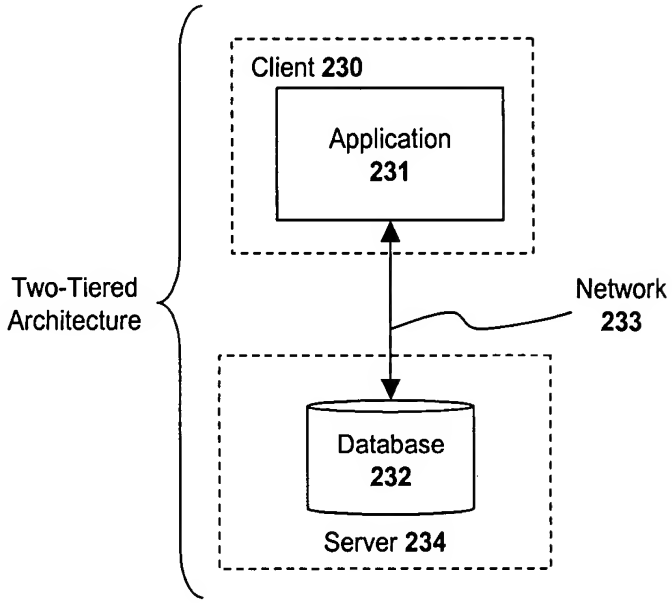


FIG. 2A
(prior art)

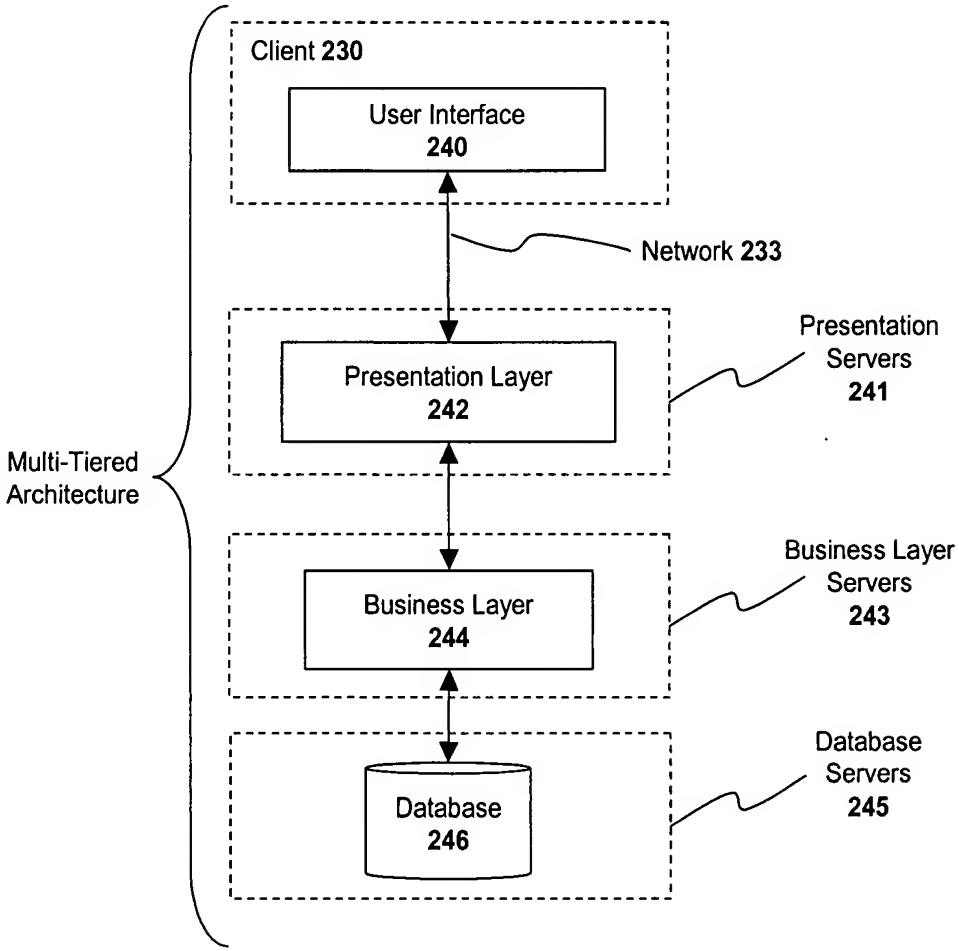


FIG. 2B
(prior art)

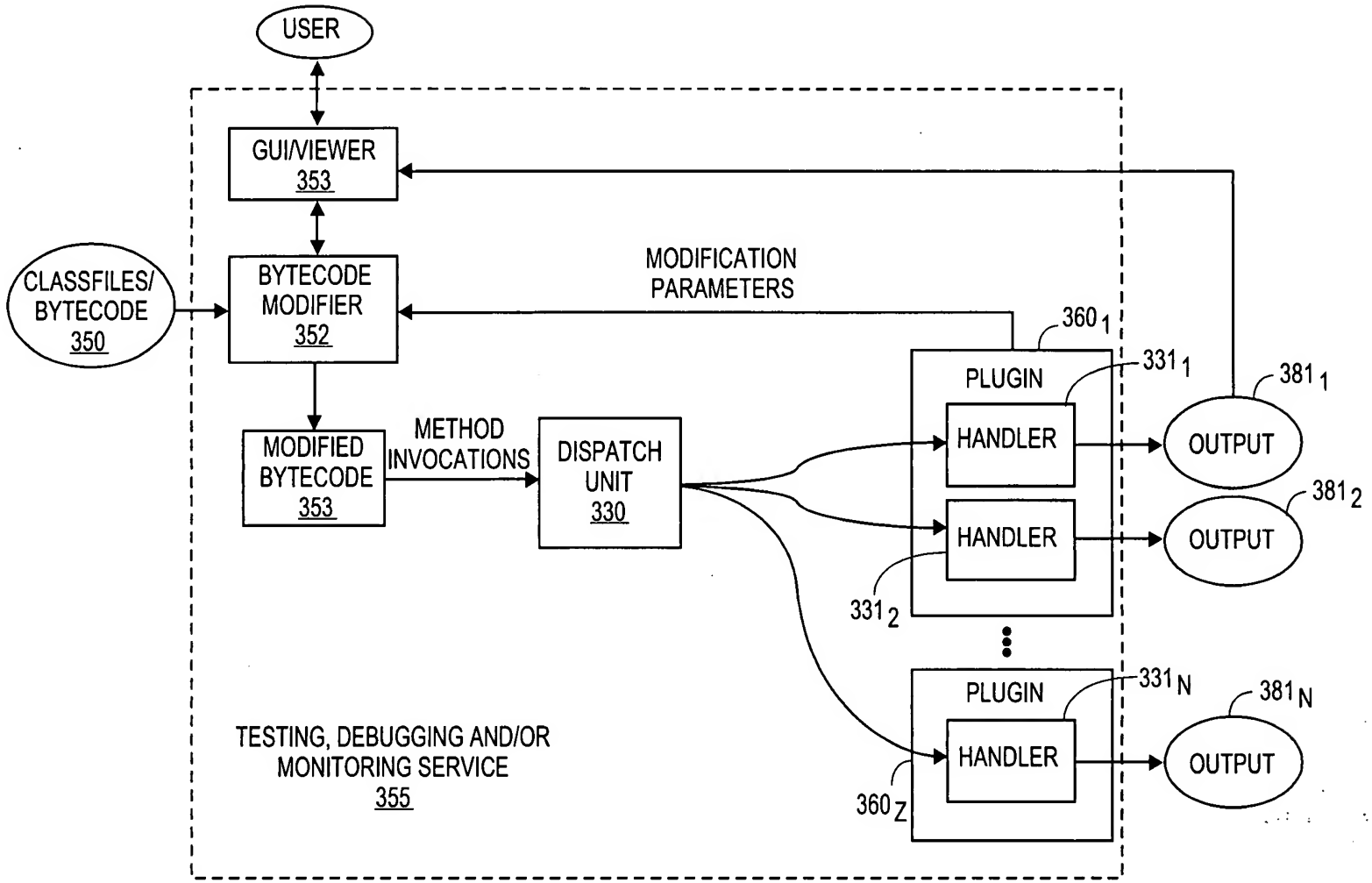

USER
GUI/VIEWER
353
CLASSFILES/
BYTECODE
350
BYTECODE
MODIFIER
352
MODIFICATION
PARAMETERS
MODIFIED
BYTECODE
353
METHOD
INVOCATIONS
DISPATCH
UNIT
330
PLUGIN
HANDLER
HANDLER
PLUGIN
HANDLER
OUTPUT
OUTPUT
OUTPUT
TESTING, DEBUGGING AND/OR
MONITORING SERVICE
355

FIG. 3

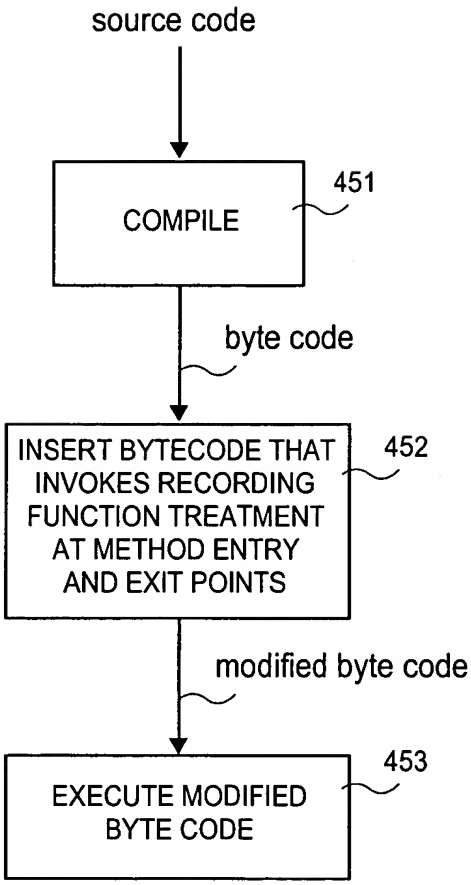

source code
COMPILE
451
byte code
INSERT BYTECODE THAT INVOKES RECORDING FUNCTION TREATMENT AT METHOD ENTRY AND EXIT POINTS
452
modified byte code
EXECUTE MODIFIED BYTE CODE
453

FIG. 4A

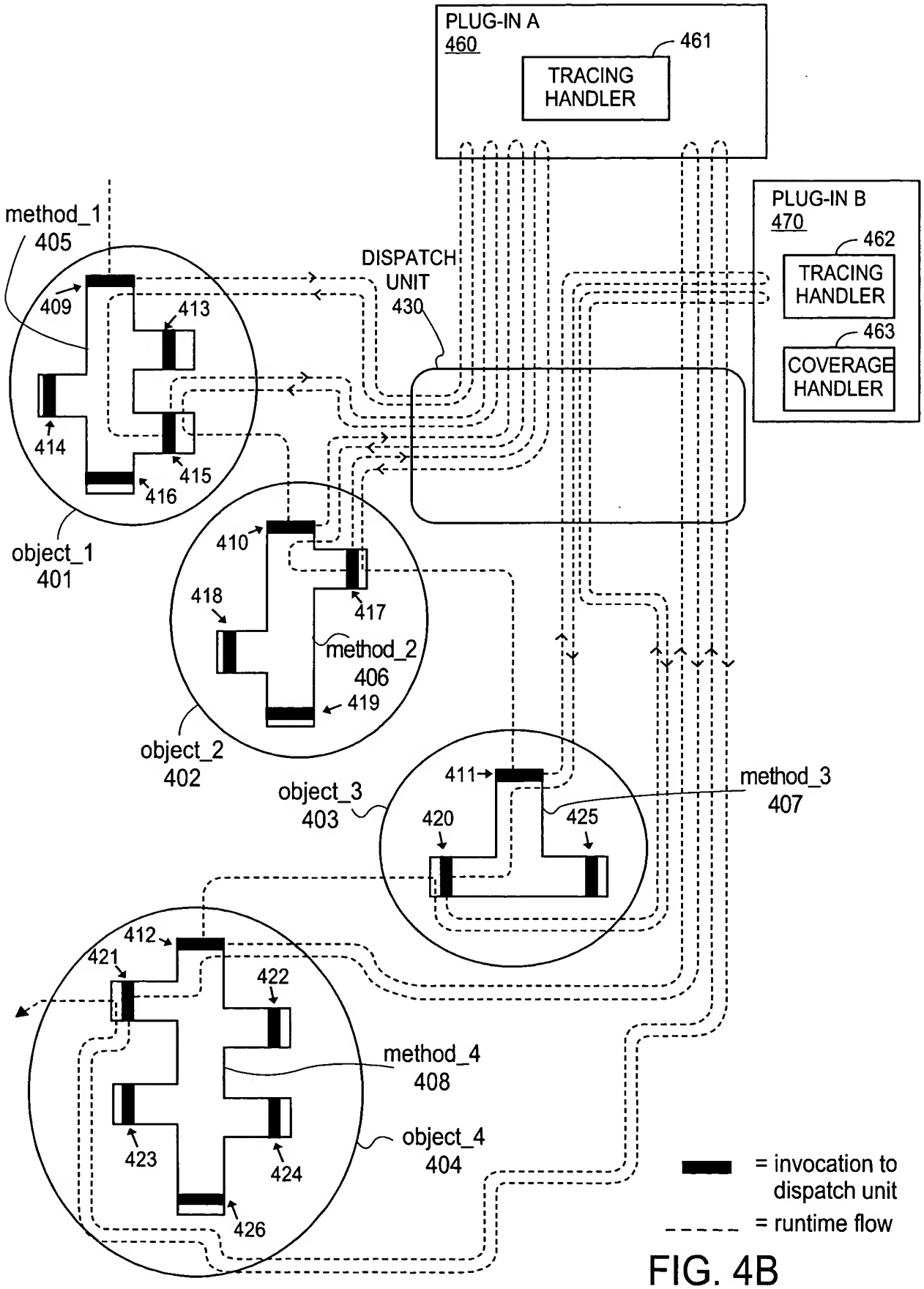

PLUG-IN A
460
461
TRACING HANDLER
PLUG-IN B
470
462
TRACING HANDLER
463
COVERAGE HANDLER
DISPATCH UNIT
430
method_1
405
409
413
414
415
416
object_1
401
410
417
418
method_2
406
419
object_2
402
object_3
403
411
420
425
method_3
407
412
421
422
method_4
408
423
424
426
object_4
404
= invocation to dispatch unit
= runtime flow

FIG. 4B

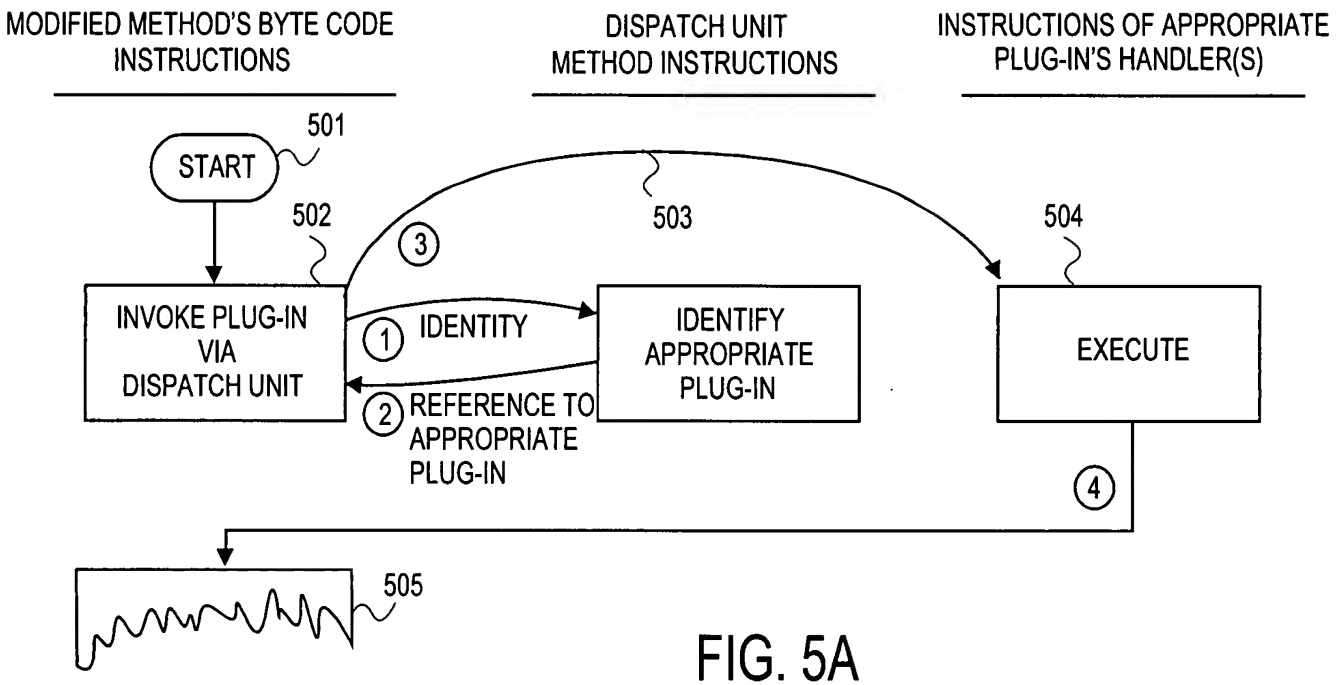

MODIFIED METHOD'S BYTE CODE INSTRUCTIONS
DISPATCH UNIT METHOD INSTRUCTIONS
INSTRUCTIONS OF APPROPRIATE PLUG-IN'S HANDLER(S)
START
501
502
503
504
INVOKE PLUG-IN VIA DISPATCH UNIT
IDENTIFY APPROPRIATE PLUG-IN
EXECUTE
1 IDENTITY
2 REFERENCE TO APPROPRIATE PLUG-IN
3
4
505

FIG. 5A

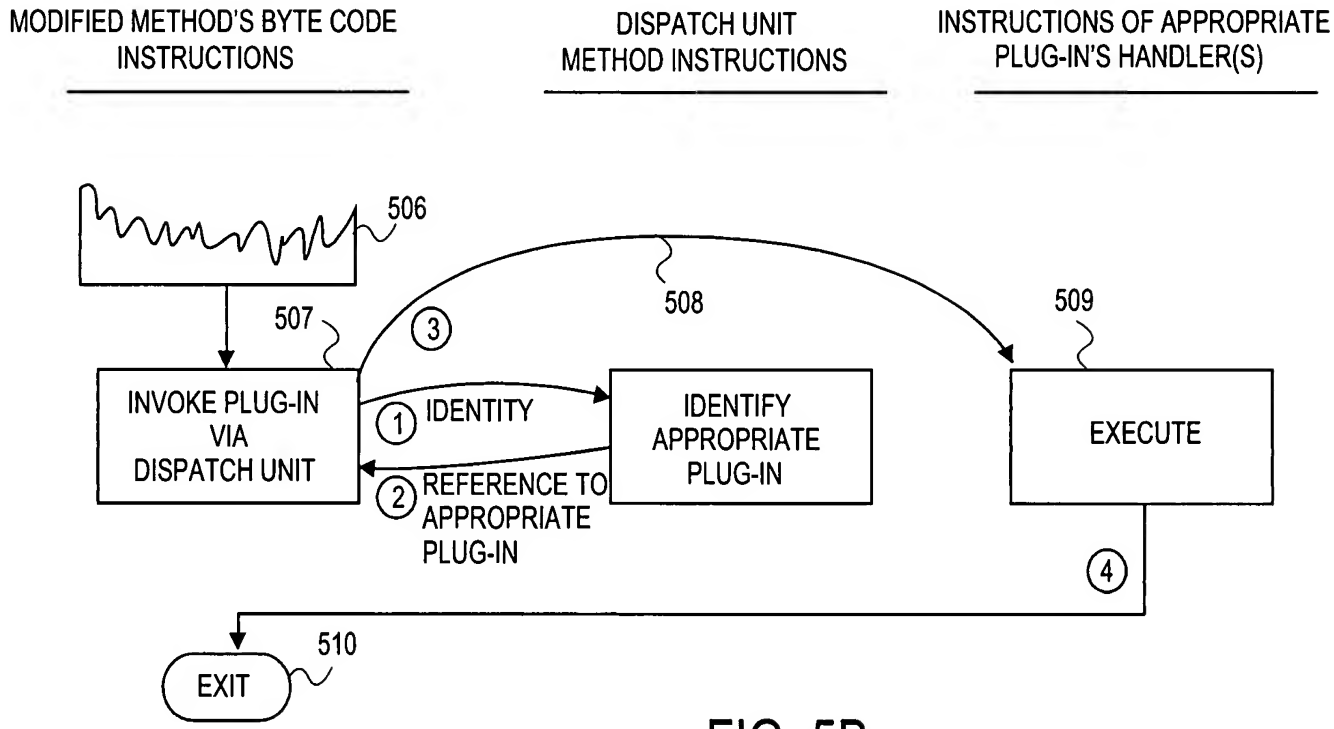

MODIFIED METHOD'S BYTE CODE INSTRUCTIONS
DISPATCH UNIT METHOD INSTRUCTIONS
INSTRUCTIONS OF APPROPRIATE PLUG-IN'S HANDLER(S)
506
507
508
509
INVOKE PLUG-IN VIA DISPATCH UNIT
1 IDENTITY
2 REFERENCE TO APPROPRIATE PLUG-IN
IDENTIFY APPROPRIATE PLUG-IN
EXECUTE
3
4
EXIT
510

FIG. 5B

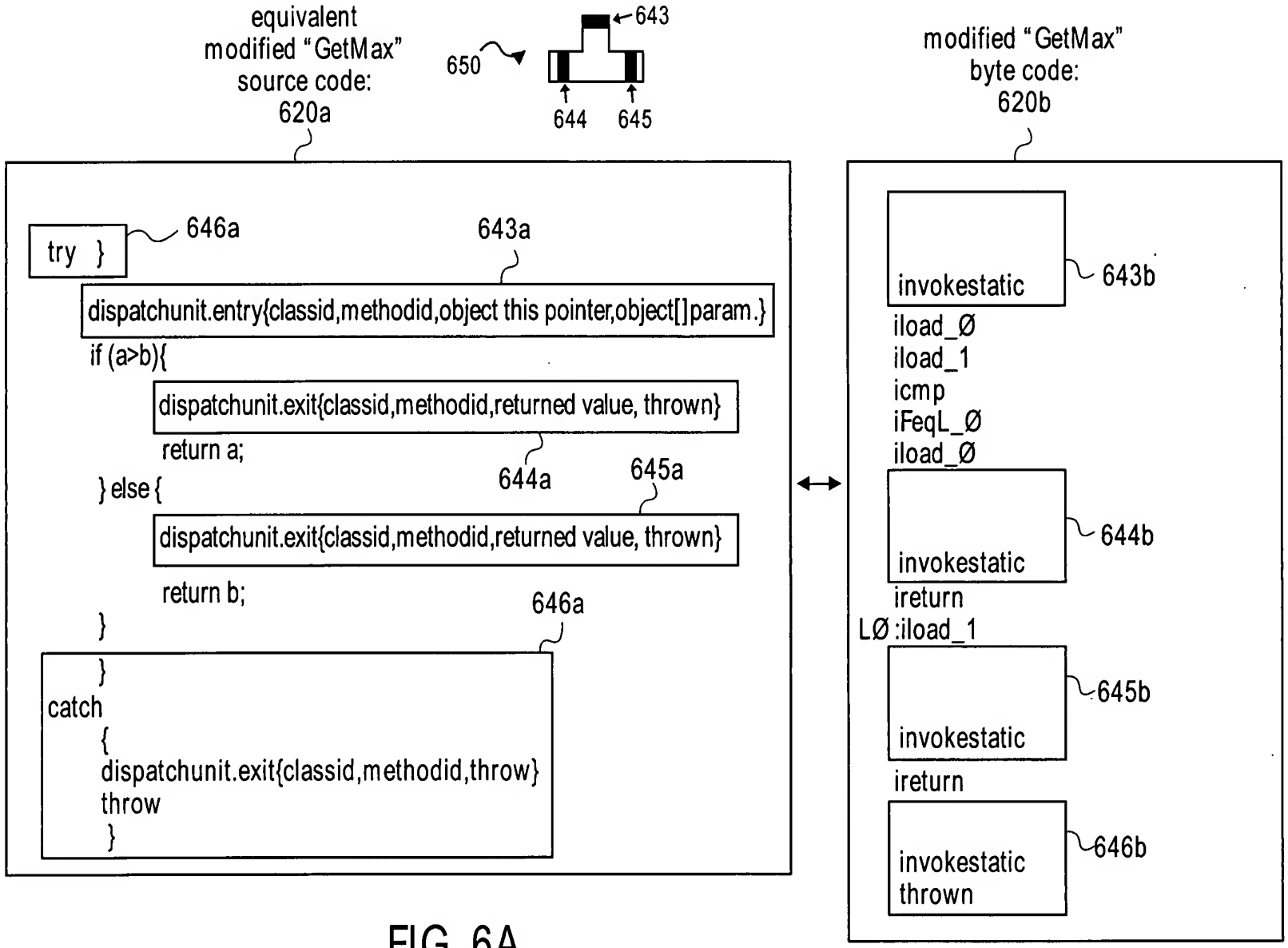

equivalent
modified "GetMax"
source code:
620a
650
643
644
645
modified "GetMax"
byte code:
620b
try }
646a
643a
dispatchunit.entry{classid,methodid,object this pointer,object[]param.}
if (a>b){
dispatchunit.exit{classid,methodid,returned value, thrown}
return a;
644a
645a
} else {
dispatchunit.exit{classid,methodid,returned value, thrown}
return b;
646a
}
}
catch
{
dispatchunit.exit{classid,methodid,throw}
throw
}
invokestatic
643b
iload_Ø
iload_1
icmp
iFeqL_Ø
iload_Ø
invokestatic
644b
ireturn
LØ :iload_1
invokestatic
645b
ireturn
invokestatic
thrown
646b

FIG. 6A

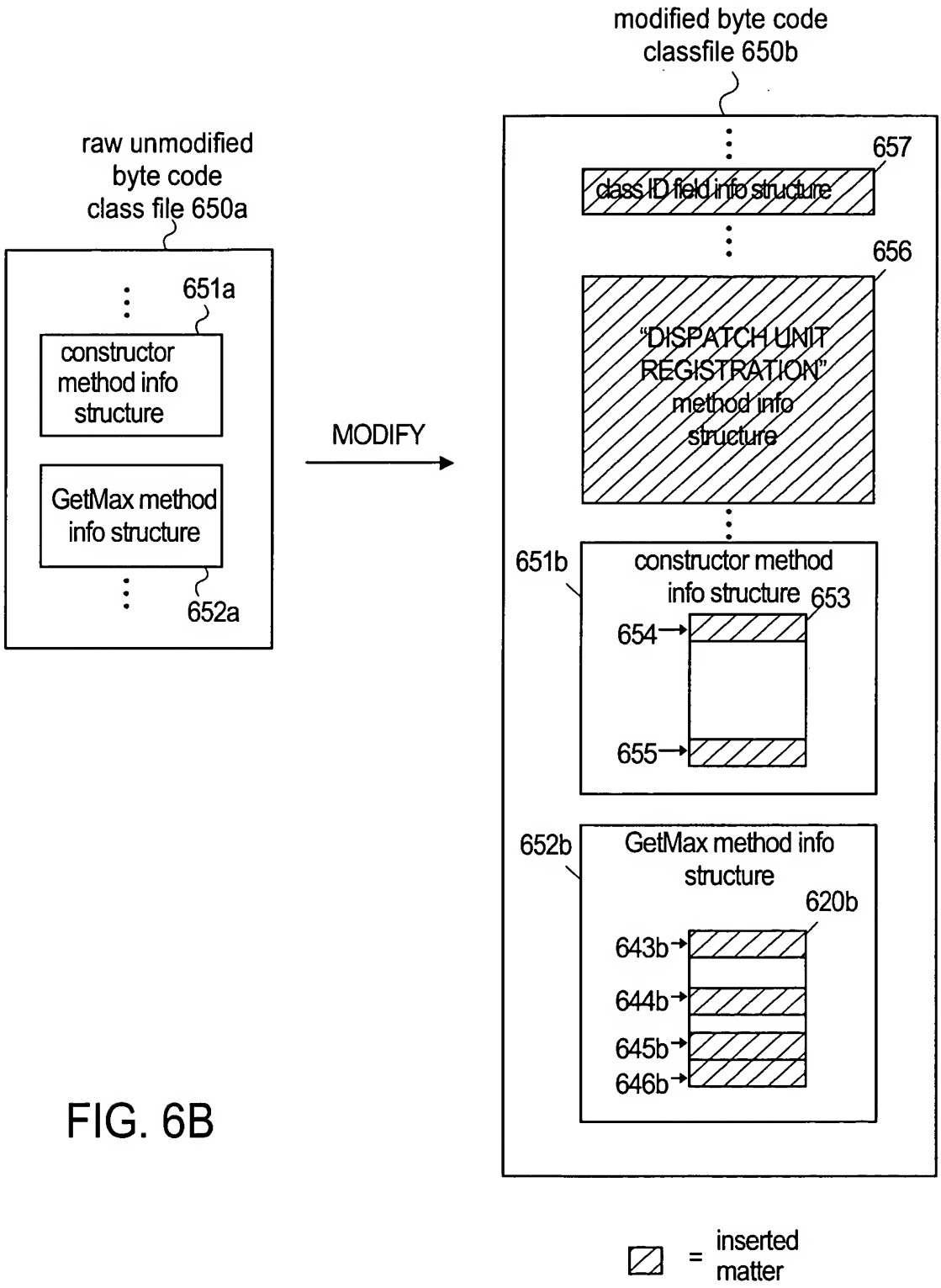

raw unmodified
byte code
class file 650a
651a
constructor
method info
structure
GetMax method
info structure
652a
MODIFY
modified byte code
classfile 650b
657
class ID field info structure
656
"DISPATCH UNIT
REGISTRATION"
method info
structure
651b
constructor method
info structure
653
654
655
652b
GetMax method info
structure
620b
643b
644b
645b
646b
= inserted
matter

FIG. 6B

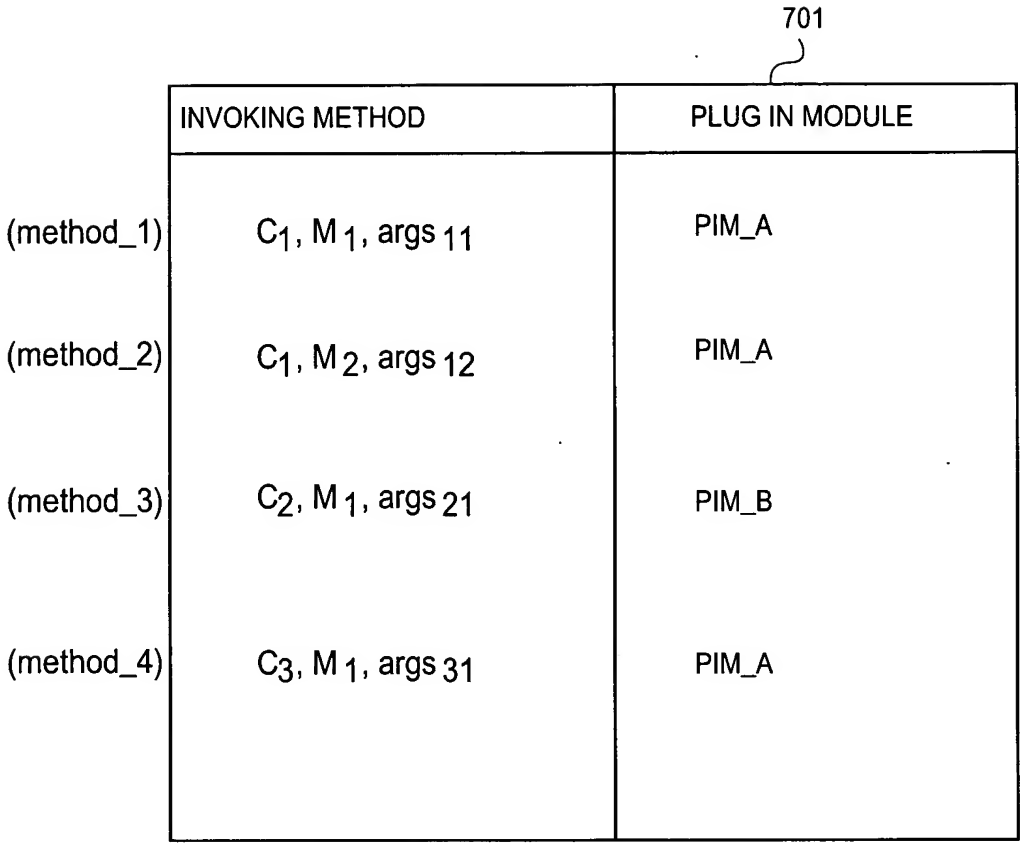

701
INVOKING METHOD
PLUG IN MODULE
(method_1)
C1, M1, args11
PIM_A
(method_2)
C1, M2, args12
PIM_A
(method_3)
C2, M1, args21
PIM_B
(method_4)
C3, M1, args31
PIM_A

FIG. 7

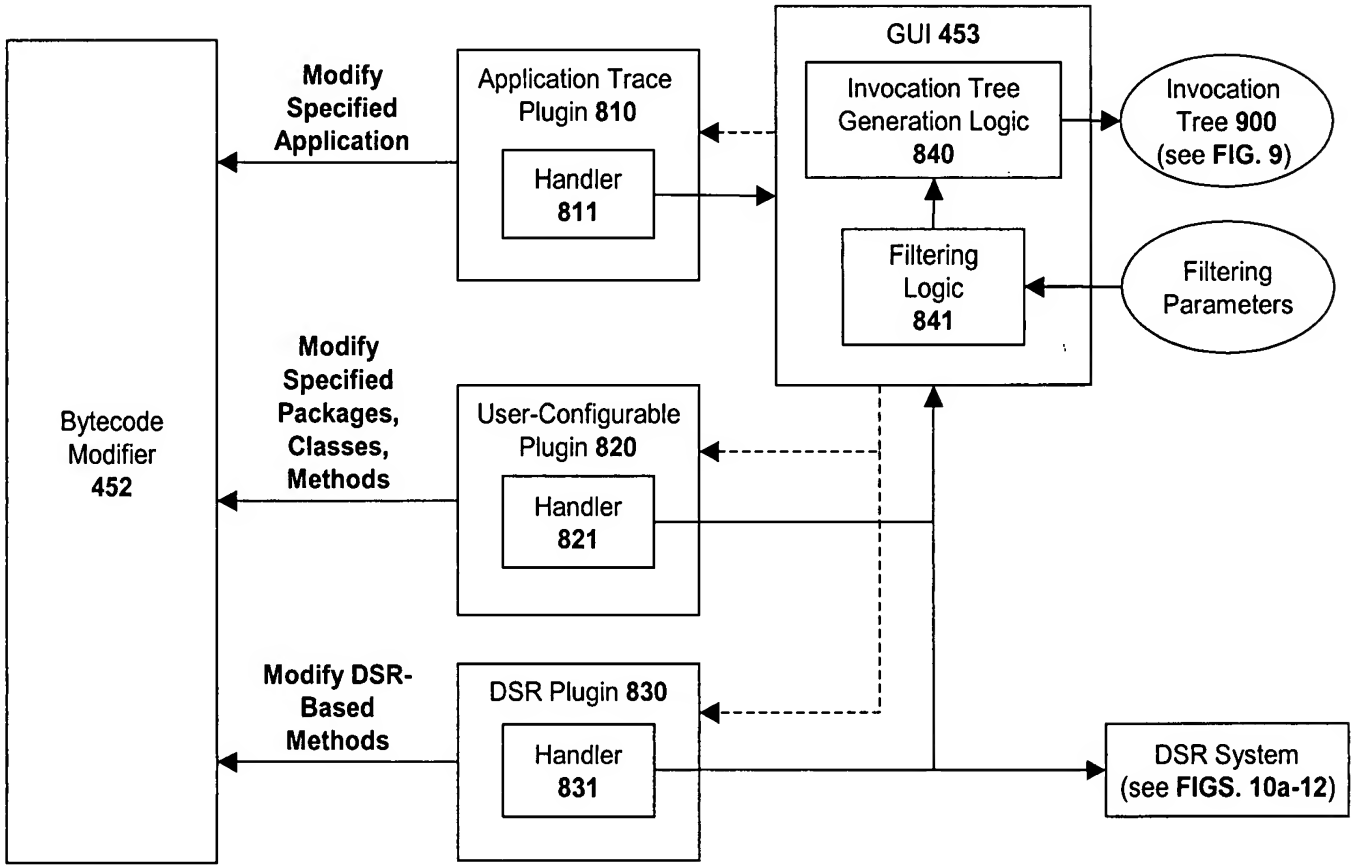

Bytecode Modifier 452
Modify Specified Application
Application Trace Plugin 810
Handler 811
Modify Specified Packages, Classes, Methods
User-Configurable Plugin 820
Handler 821
Modify DSR-Based Methods
DSR Plugin 830
Handler 831
GUI 453
Invocation Tree Generation Logic 840
Filtering Logic 841
Invocation Tree 900 (see FIG. 9)
Filtering Parameters
DSR System (see FIGS. 10a-12)

FIG. 8

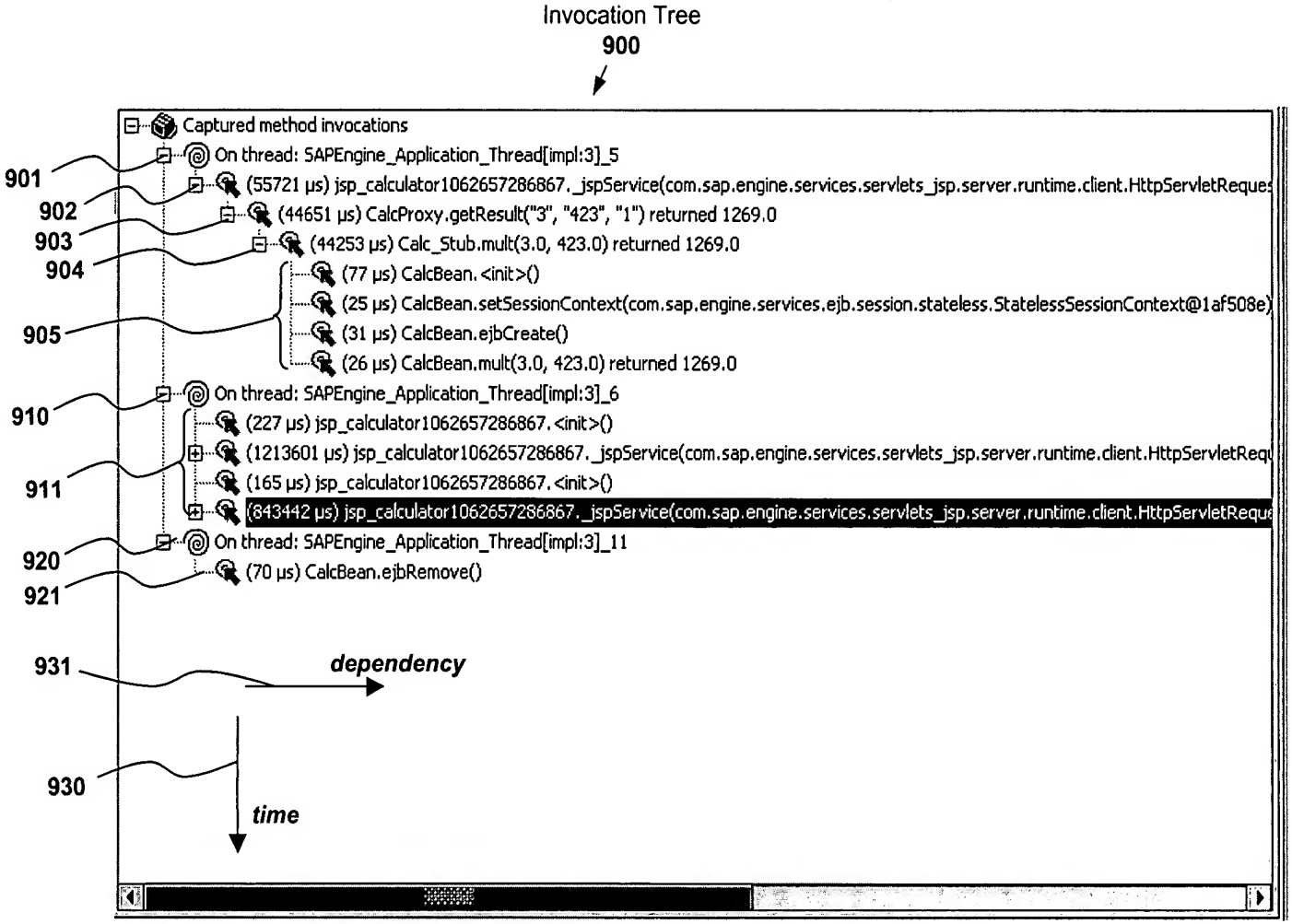

Invocation Tree
900
Captured method invocations
On thread: SAPEngine_Application_Thread[impl:3]_5
(55721 µs) jsp_calculator1062657286867._jspService(com.sap.engine.services.servlets_jsp.server.runtime.client.HttpServletReques
(44651 µs) CalcProxy.getResult("3", "423", "1") returned 1269.0
(44253 µs) Calc_Stub.mult(3.0, 423.0) returned 1269.0
(77 µs) CalcBean.<init>()
(25 µs) CalcBean.setSessionContext(com.sap.engine.services.ejb.session.stateless.StatelessSessionContext@1af508e)
(31 µs) CalcBean.ejbCreate()
(26 µs) CalcBean.mult(3.0, 423.0) returned 1269.0
On thread: SAPEngine_Application_Thread[impl:3]_6
(227 µs) jsp_calculator1062657286867.<init>()
(1213601 µs) jsp_calculator1062657286867._jspService(com.sap.engine.services.servlets_jsp.server.runtime.client.HttpServletRequ
(165 µs) jsp_calculator1062657286867.<init>()
(843442 µs) jsp_calculator1062657286867._jspService(com.sap.engine.services.servlets_jsp.server.runtime.client.HttpServletReque
On thread: SAPEngine_Application_Thread[impl:3]_11
(70 µs) CalcBean.ejbRemove()
901
902
903
904
905
910
911
920
921
931
dependency
930
time

FIG. 9A

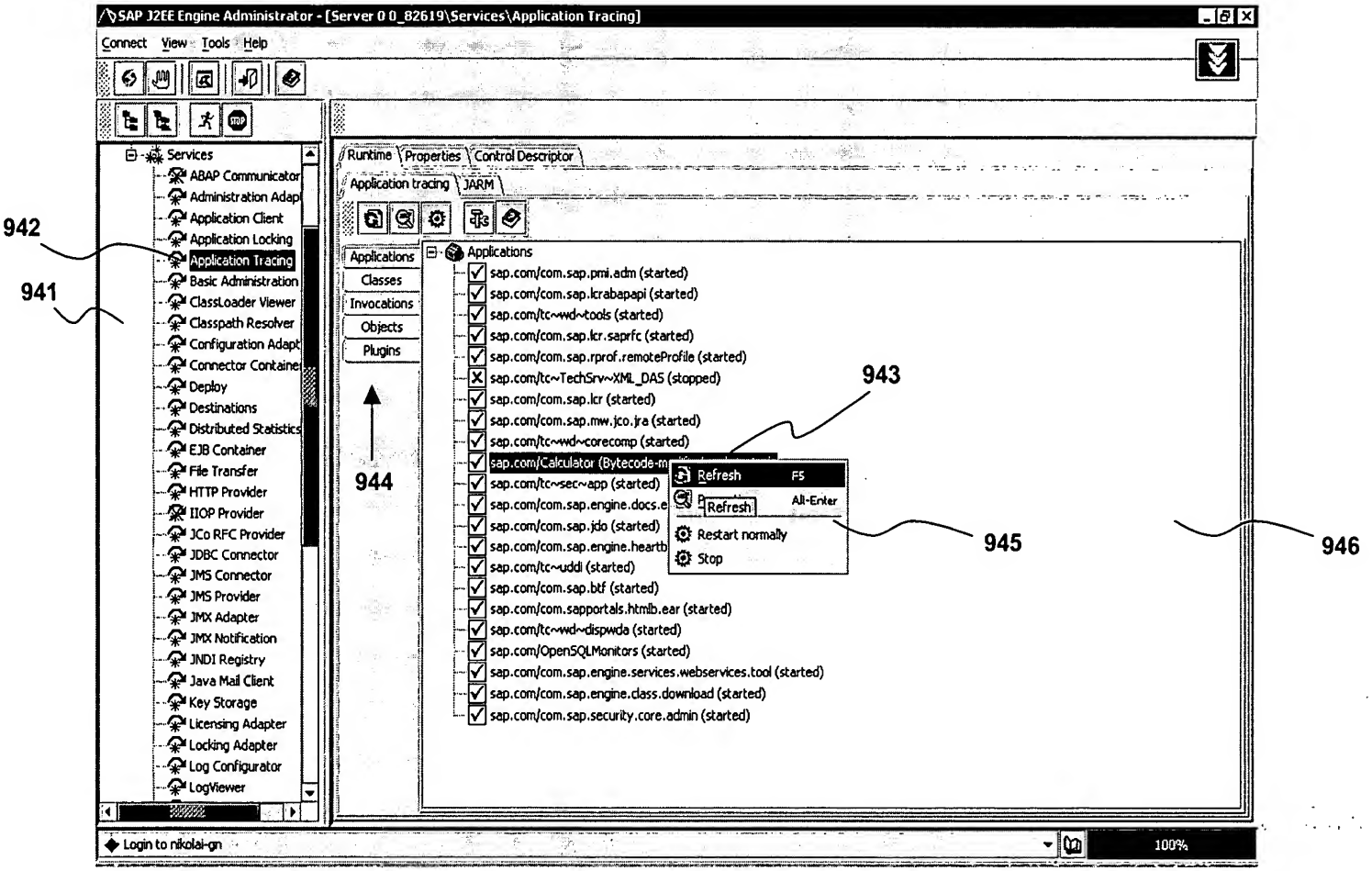

SAP J2EE Engine Administrator - [Server 0 0_82619\Services\Application Tracing]
Connect View Tools Help
Services
ABAP Communicator
Administration Adapt
Application Client
Application Locking
Application Tracing
Basic Administration
ClassLoader Viewer
Classpath Resolver
Configuration Adapt
Connector Containe
Deploy
Destinations
Distributed Statistics
EJB Container
File Transfer
HTTP Provider
IIOP Provider
JCo RFC Provider
JDBC Connector
JMS Connector
JMS Provider
JMX Adapter
JMX Notification
JNDI Registry
Java Mail Client
Key Storage
Licensing Adapter
Locking Adapter
Log Configurator
LogViewer
Runtime
Properties
Control Descriptor
Application tracing
JARM
Applications
Classes
Invocations
Objects
Plugins
Applications
sap.com/com.sap.pmi.adm (started)
sap.com/com.sap.lcrabapapi (started)
sap.com/tc~wd~tools (started)
sap.com/com.sap.lcr.saprfc (started)
sap.com/com.sap.rprof.remoteProfile (started)
sap.com/tc~TechSrv~XML_DAS (stopped)
sap.com/com.sap.lcr (started)
sap.com/com.sap.mw.jco.jra (started)
sap.com/tc~wd~corecomp (started)
sap.com/Calculator (Bytecode-m
sap.com/tc~sec~app (started)
sap.com/com.sap.engine.docs.e
sap.com/com.sap.jdo (started)
sap.com/com.sap.engine.heartb
sap.com/tc~uddi (started)
sap.com/com.sap.btf (started)
sap.com/com.sapportals.htmlb.ear (started)
sap.com/tc~wd~dispwda (started)
sap.com/OpenSQLMonitors (started)
sap.com/com.sap.engine.services.webservices.tool (started)
sap.com/com.sap.engine.class.download (started)
sap.com/com.sap.security.core.admin (started)
Refresh F5
Refresh Alt-Enter
Restart normally
Stop
Login to nikolai-gn
100%
942
941
943
944
945
946

FIG. 9B

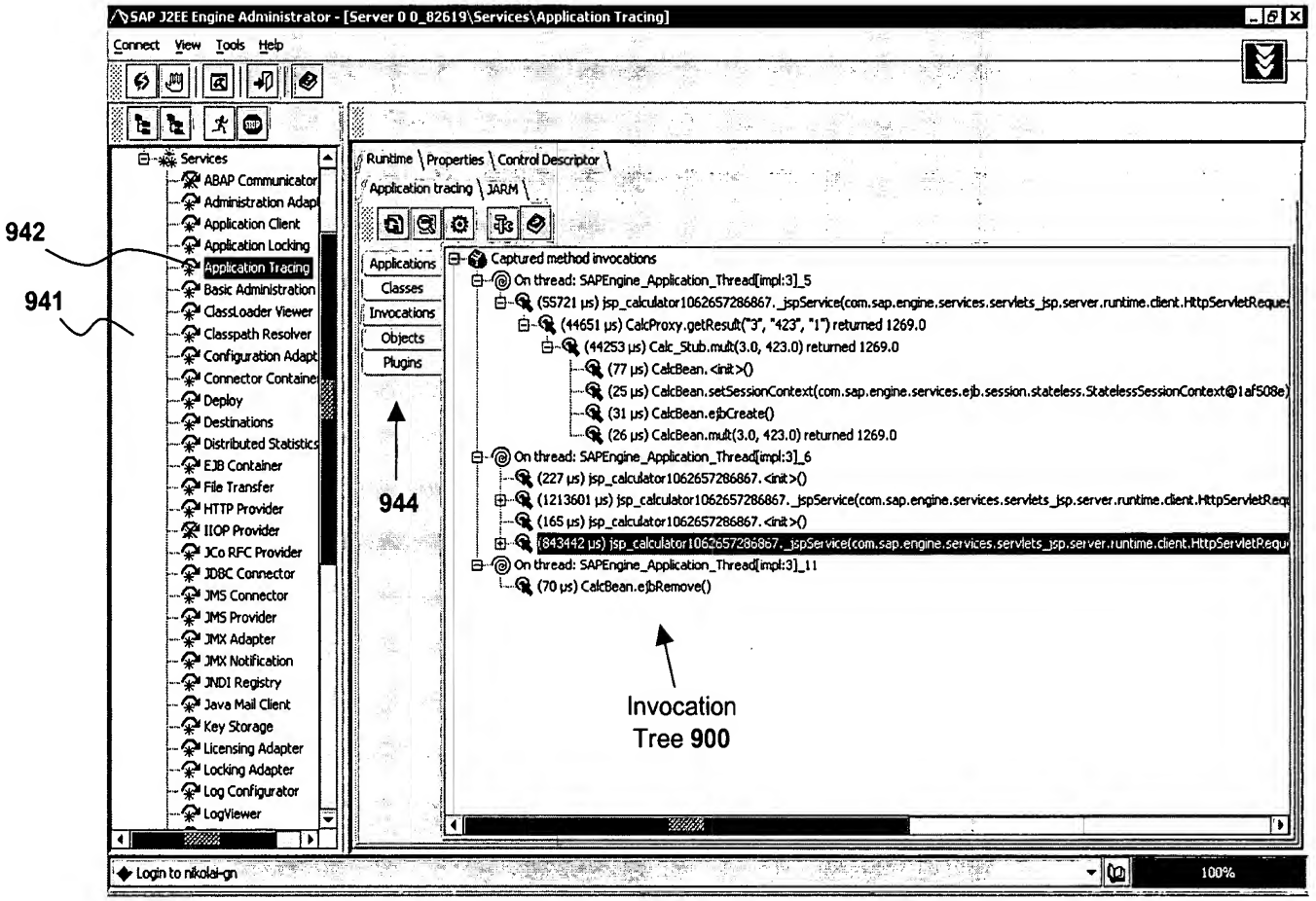
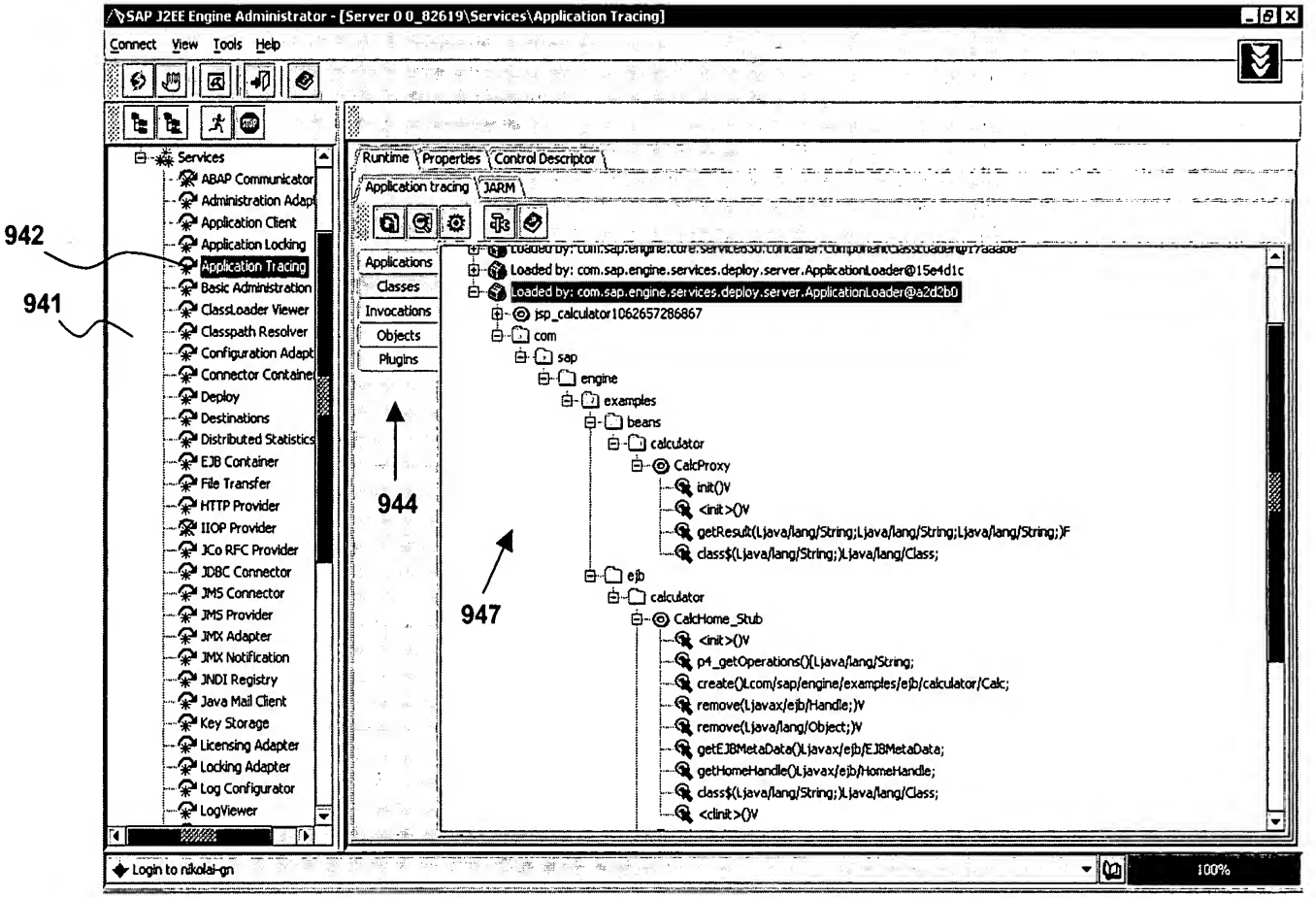

SAP J2EE Engine Administrator - [Server 0 0_82619\Services\Application Tracing]
Connect View Tools Help
Services
ABAP Communicator
Administration Adapt
Application Client
Application Locking
Application Tracing
Basic Administration
ClassLoader Viewer
Classpath Resolver
Configuration Adapt
Connector Containe
Deploy
Destinations
Distributed Statistics
EJB Container
File Transfer
HTTP Provider
IIOP Provider
JCo RFC Provider
JDBC Connector
JMS Connector
JMS Provider
JMX Adapter
JMX Notification
JNDI Registry
Java Mail Client
Key Storage
Licensing Adapter
Locking Adapter
Log Configurator
LogViewer
Runtime \ Properties \ Control Descriptor \
Application tracing \ JARM \
Applications
Classes
Invocations
Objects
Plugins
Captured method invocations
On thread: SAPEngine_Application_Thread[impl:3]_5
(55721 µs) jsp_calculator1062657286867._jspService(com.sap.engine.services.servlets_jsp.server.runtime.client.HttpServletReque
(44651 µs) CalcProxy.getResult("3", "423", "1") returned 1269.0
(44253 µs) Calc_Stub.mult(3.0, 423.0) returned 1269.0
(77 µs) CalcBean.<init>()
(25 µs) CalcBean.setSessionContext(com.sap.engine.services.ejb.session.stateless.StatelessSessionContext@1af508e)
(31 µs) CalcBean.ejbCreate()
(26 µs) CalcBean.mult(3.0, 423.0) returned 1269.0
On thread: SAPEngine_Application_Thread[impl:3]_6
(227 µs) jsp_calculator1062657286867.<init>()
(1213601 µs) jsp_calculator1062657286867._jspService(com.sap.engine.services.servlets_jsp.server.runtime.client.HttpServletReq
(165 µs) jsp_calculator1062657286867.<init>()
(843442 µs) jsp_calculator1062657286867._jspService(com.sap.engine.services.servlets_jsp.server.runtime.client.HttpServletRequ
On thread: SAPEngine_Application_Thread[impl:3]_11
(70 µs) CalcBean.ejbRemove()
Login to nikolai-gn
100%
942
941
944
Invocation Tree 900

FIG. 9C


SAP J2EE Engine Administrator - [Server 0 0_82619\Services\Application Tracing]
Connect View Tools Help
Services
ABAP Communicator
Administration Adapt
Application Client
Application Locking
Application Tracing
Basic Administration
ClassLoader Viewer
Classpath Resolver
Configuration Adapt
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Destinations
Distributed Statistics
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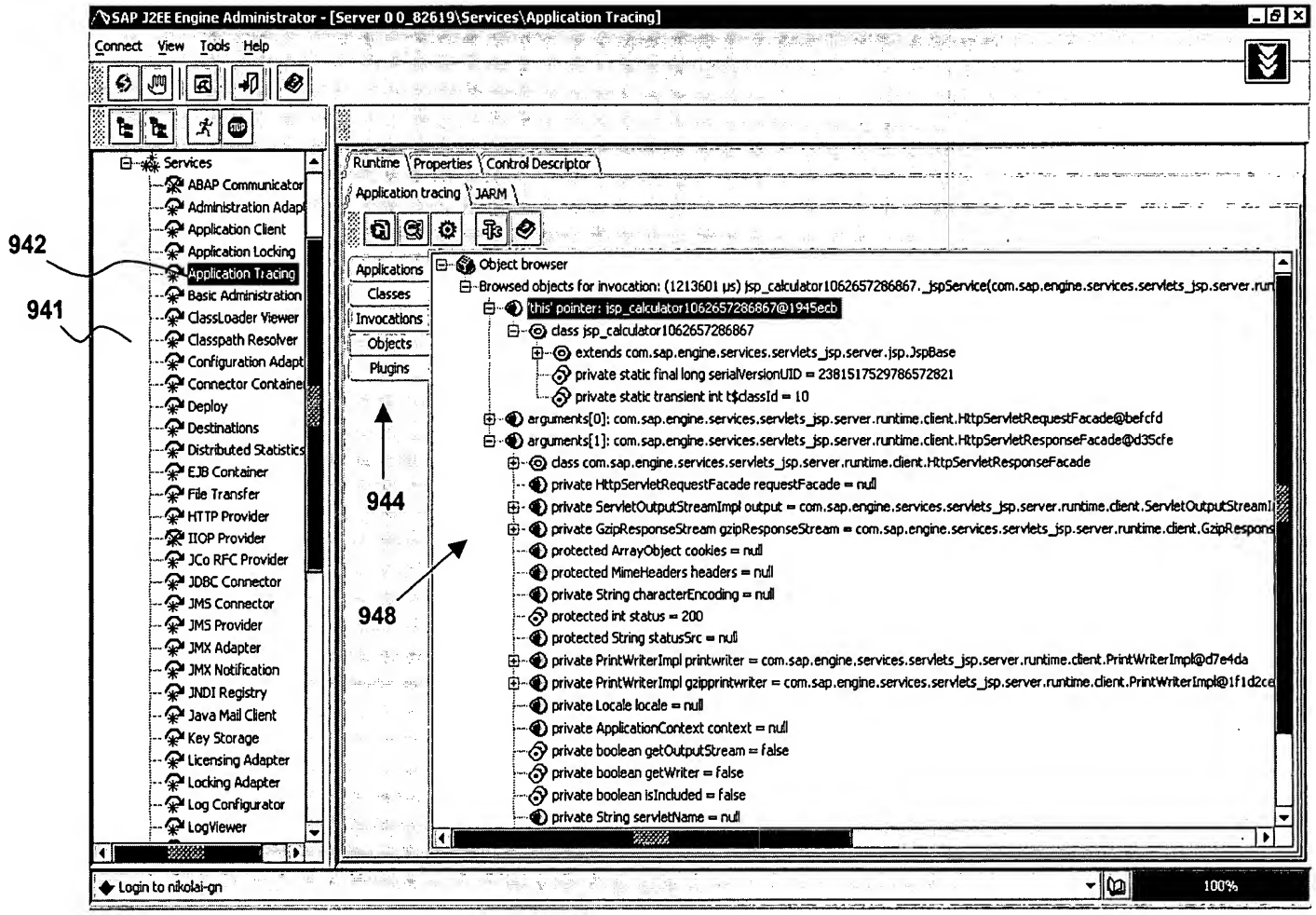
JMS Provider
JMX Adapter
JMX Notification
JNDI Registry
Java Mail Client
Key Storage
Licensing Adapter
Locking Adapter
Log Configurator
LogViewer
Runtime
Properties
Control Descriptor
Application tracing
JARM
Applications
Classes
Invocations
Objects
Plugins
Loaded by: com.sap.engine.services.deploy.server.ApplicationLoader@15e4d1c
Loaded by: com.sap.engine.services.deploy.server.ApplicationLoader@a2d2b0
jsp_calculator1062657286867
com
sap
engine
examples
beans
calculator
CalcProxy
init()V
<init>()V
getResult(Ljava/lang/String;Ljava/lang/String;Ljava/lang/String;)F
class$(Ljava/lang/String;)Ljava/lang/Class;
ejb
calculator
CalcHome_Stub
<init>()V
p4_getOperations()[Ljava/lang/String;
create()Lcom/sap/engine/examples/ejb/calculator/Calc;
remove(Ljavax/ejb/Handle;)V
remove(Ljava/lang/Object;)V
getEJBMetaData()Ljavax/ejb/EJBMetaData;
getHomeHandle()Ljavax/ejb/HomeHandle;
class$(Ljava/lang/String;)Ljava/lang/Class;
<clinit>()V
Login to nikolai-gn
100%
942
941
944
947

FIG. 9D


SAP J2EE Engine Administrator - [Server 0 0_82619\Services\Application Tracing]
Connect View Tools Help
Services
ABAP Communicator
Administration Adapt
Application Client
Application Locking
Application Tracing
Basic Administration
ClassLoader Viewer
Classpath Resolver
Configuration Adapt
Connector Containe
Deploy
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HTTP Provider
IIOP Provider
JCo RFC Provider
JDBC Connector
JMS Connector
JMS Provider
JMX Adapter
JMX Notification
JNDI Registry
Java Mail Client
Key Storage
Licensing Adapter
Locking Adapter
Log Configurator
LogViewer
Runtime
Properties
Control Descriptor
Application tracing
JARM
Applications
Classes
Invocations
Objects
Plugins
Object browser
Browsed objects for invocation: (1213601 µs) jsp_calculator1062657286867._jspService(com.sap.engine.services.servlets_jsp.server.run
'this' pointer: jsp_calculator1062657286867@1945ecb
class jsp_calculator1062657286867
extends com.sap.engine.services.servlets_jsp.server.jsp.JspBase
private static final long serialVersionUID = 2381517529786572821
private static transient int t$classId = 10
arguments[0]: com.sap.engine.services.servlets_jsp.server.runtime.client.HttpServletRequestFacade@befcfd
arguments[1]: com.sap.engine.services.servlets_jsp.server.runtime.client.HttpServletResponseFacade@d35cfe
class com.sap.engine.services.servlets_jsp.server.runtime.client.HttpServletResponseFacade
private HttpServletRequestFacade requestFacade = null
private ServletOutputStreamImpl output = com.sap.engine.services.servlets_jsp.server.runtime.client.ServletOutputStreamI
private GzipResponseStream gzipResponseStream = com.sap.engine.services.servlets_jsp.server.runtime.client.GzipRespons
protected ArrayObject cookies = null
protected MimeHeaders headers = null
private String characterEncoding = null
protected int status = 200
protected String statusSrc = null
private PrintWriterImpl printwriter = com.sap.engine.services.servlets_jsp.server.runtime.client.PrintWriterImpl@d7e4da
private PrintWriterImpl gzipprintwriter = com.sap.engine.services.servlets_jsp.server.runtime.client.PrintWriterImpl@1f1d2ce
private Locale locale = null
private ApplicationContext context = null
private boolean getOutputStream = false
private boolean getWriter = false
private boolean isIncluded = false
private String servletName = null
942
941
944
948
Login to nikolai-gn
100%

FIG. 9E

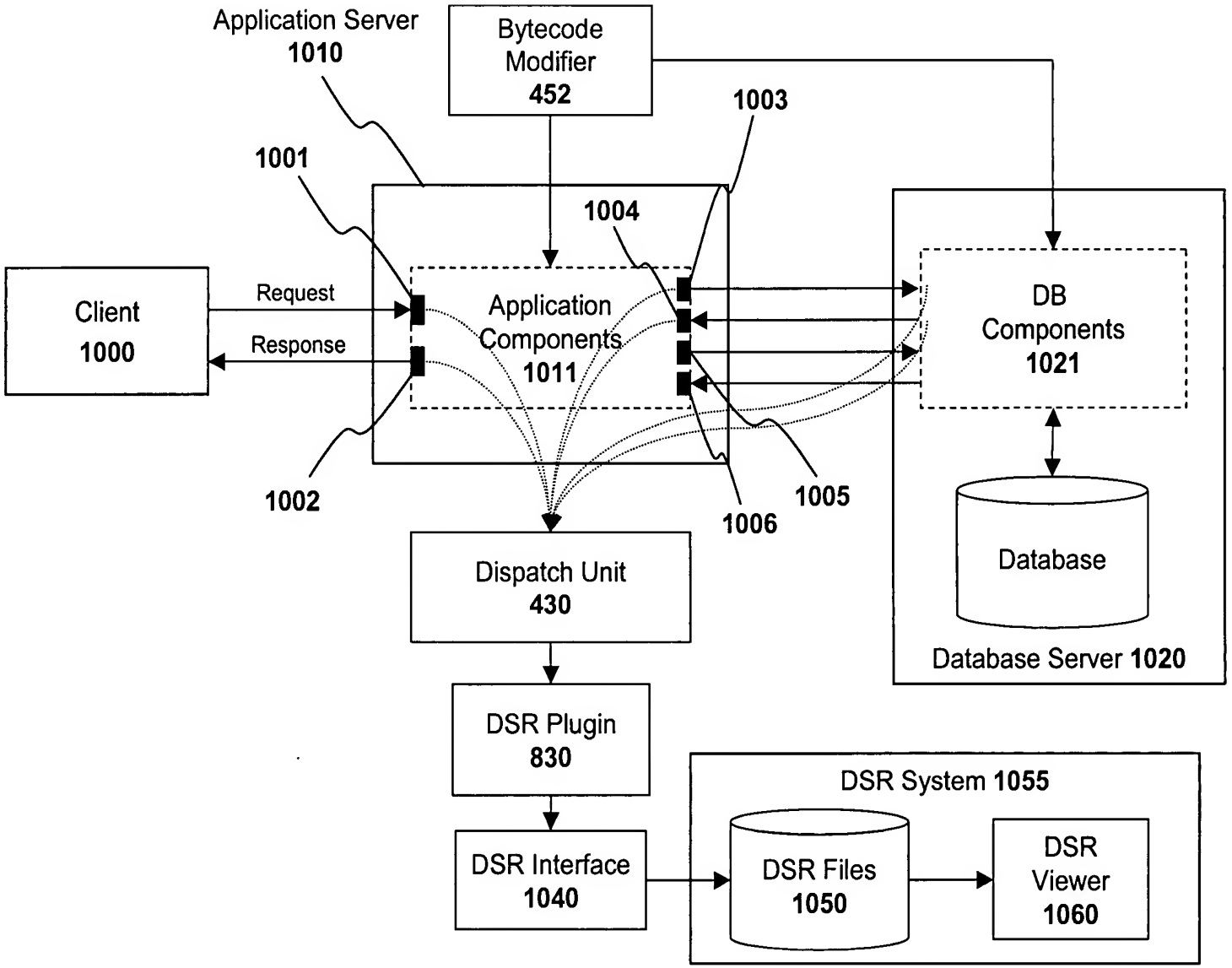

Application Server
1010
Bytecode
Modifier
452
1003
1001
1004
Client
1000
Request
Response
Application
Components
1011
DB
Components
1021
1002
1006
1005
Database
Dispatch Unit
430
Database Server 1020
DSR Plugin
830
DSR System 1055
DSR Interface
1040
DSR Files
1050
DSR
Viewer
1060

FIG. 10A

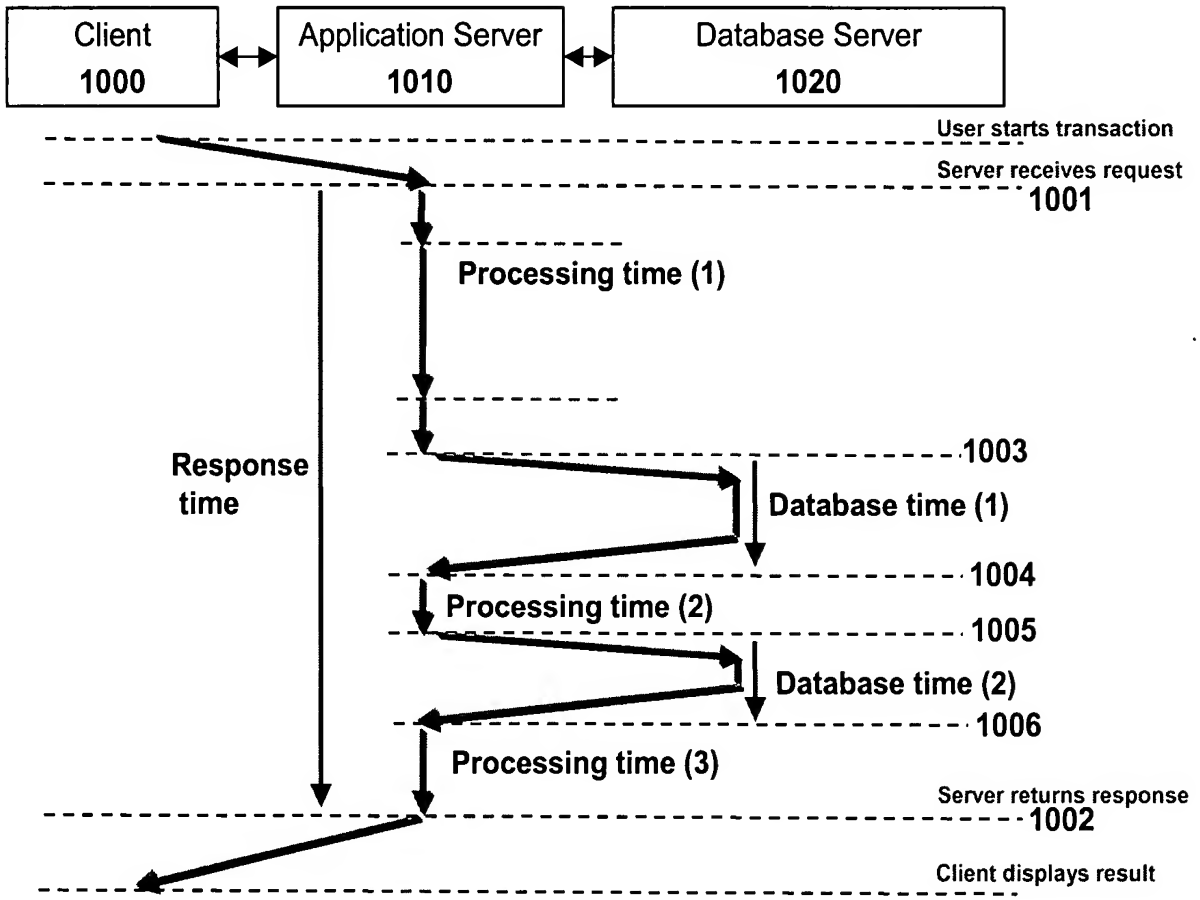

Client
1000
Application Server
1010
Database Server
1020
User starts transaction
Server receives request
1001
Processing time (1)
1003
Response time
Database time (1)
1004
Processing time (2)
1005
Database time (2)
1006
Processing time (3)
Server returns response
1002
Client displays result

FIG. 10B

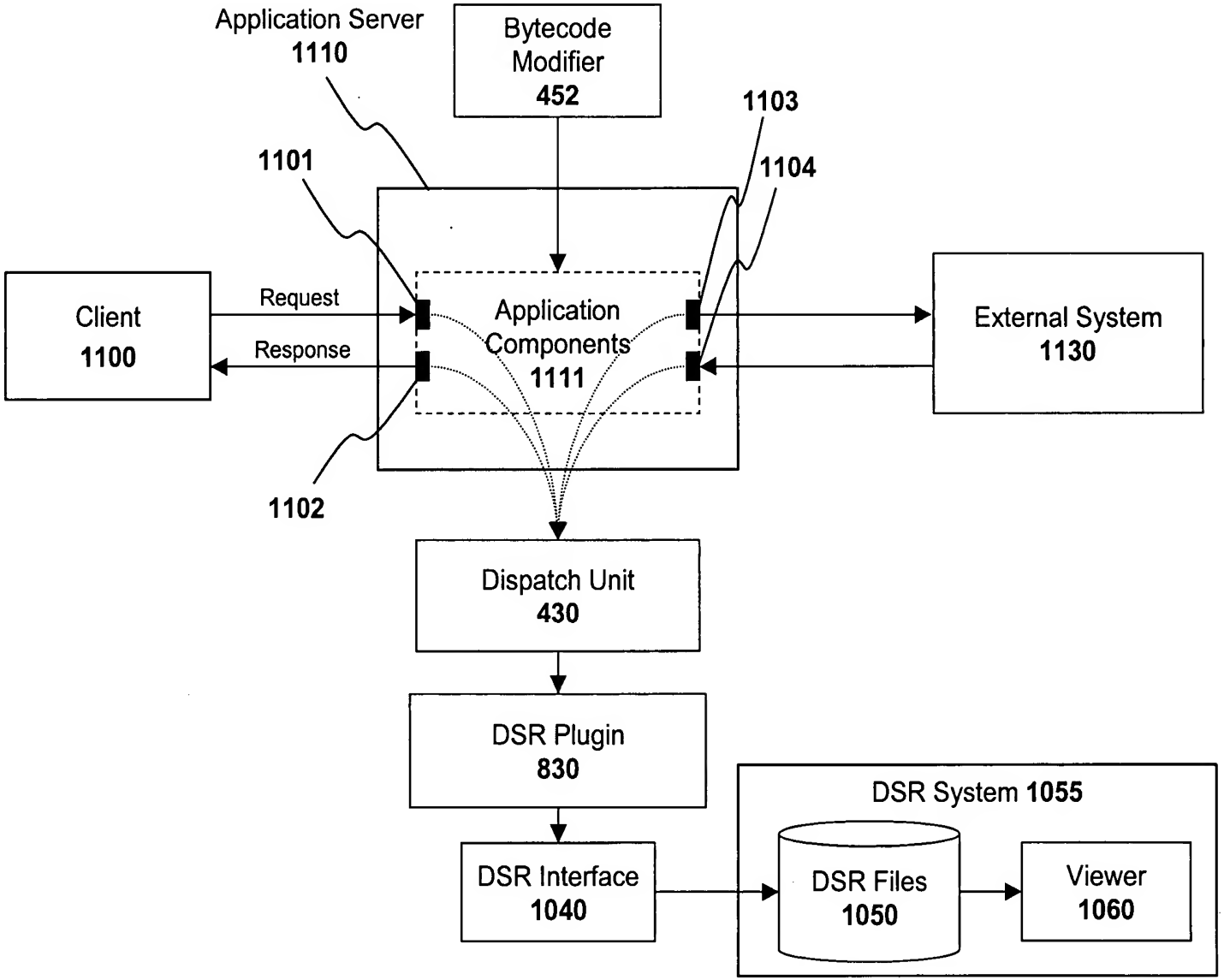

Application Server
1110
Bytecode
Modifier
452
1103
1101
1104
Client
1100
Request
Response
Application
Components
1111
External System
1130
1102
Dispatch Unit
430
DSR Plugin
830
DSR System 1055
DSR Interface
1040
DSR Files
1050
Viewer
1060

FIG. 11A

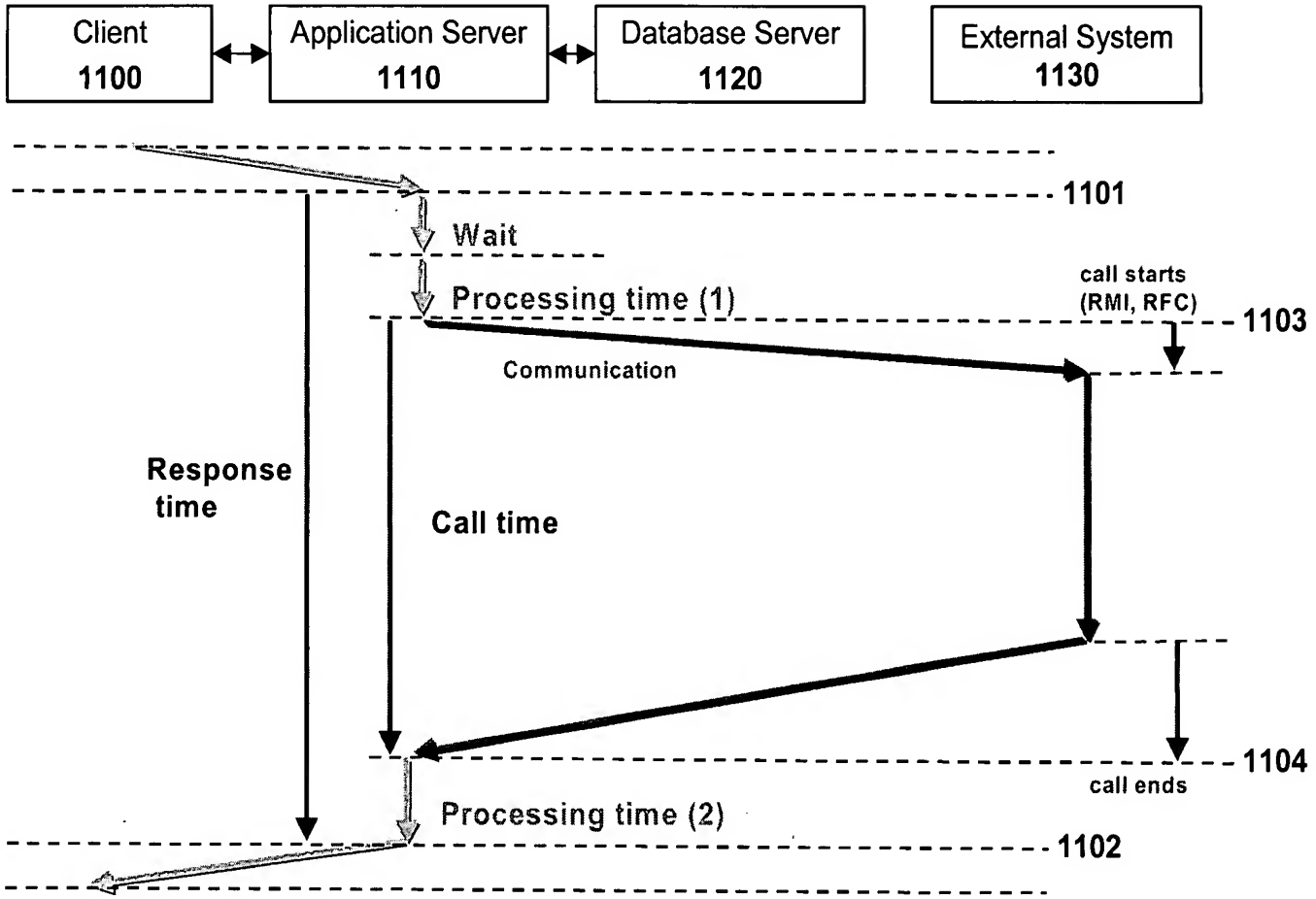

Client
1100
Application Server
1110
Database Server
1120
External System
1130
1101
Wait
Processing time (1)
call starts
(RMI, RFC)
1103
Communication
Response
time
Call time
1104
call ends
Processing time (2)
1102

FIG. 11B

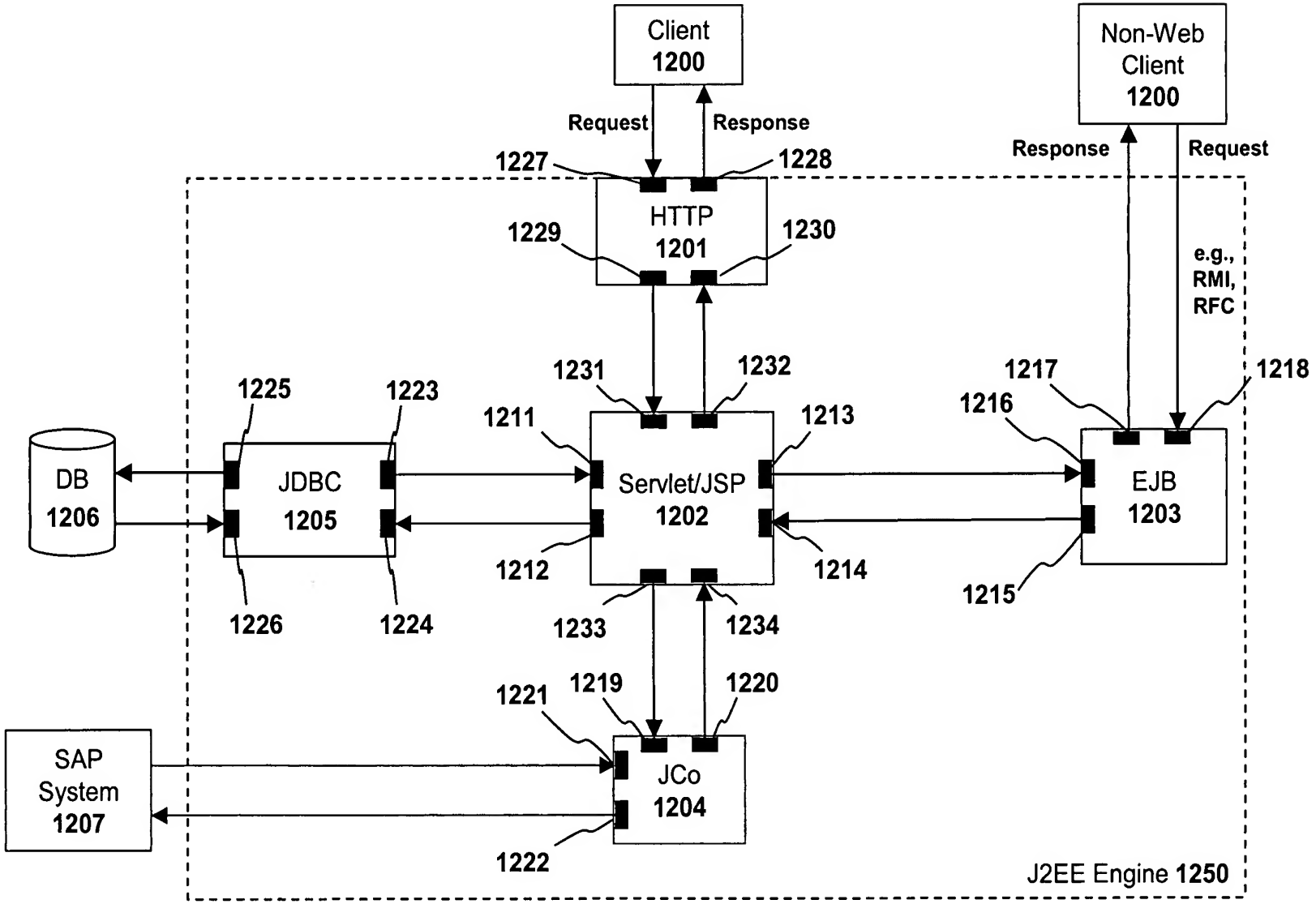

Client
1200
Non-Web
Client
1200
Request
Response
Response
Request
1227
1228
HTTP
1201
1229
1230
e.g.,
RMI,
RFC
1231
1232
1217
1218
1225
1223
1211
1213
1216
DB
1206
JDBC
1205
Servlet/JSP
1202
EJB
1203
1212
1214
1215
1226
1224
1233
1234
1219
1220
1221
SAP
System
1207
JCo
1204
1222
J2EE Engine 1250

FIG. 12

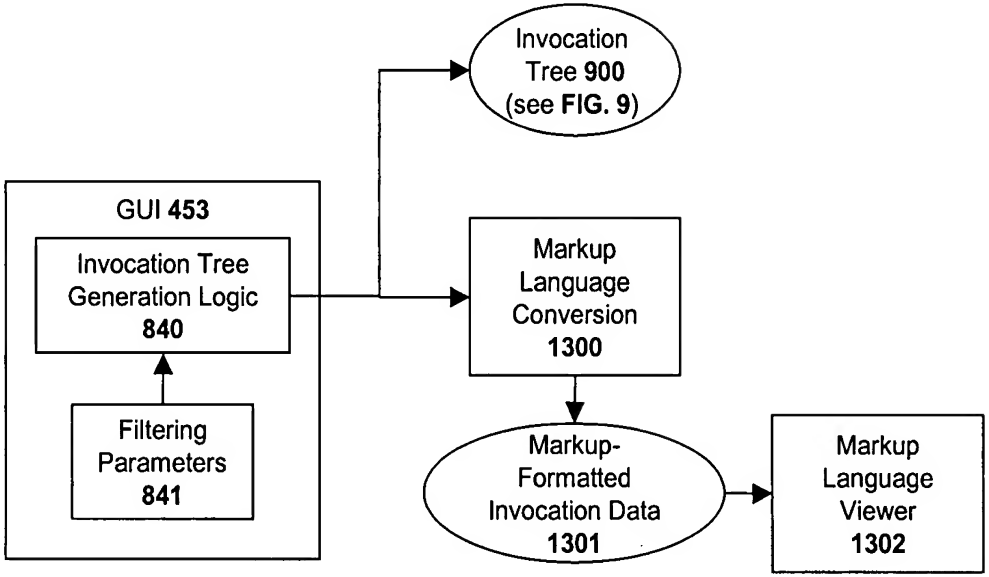

Invocation Tree 900 (see FIG. 9)
GUI 453
Invocation Tree Generation Logic 840
Filtering Parameters 841
Markup Language Conversion 1300
Markup-Formatted Invocation Data 1301
Markup Language Viewer 1302

FIG. 13

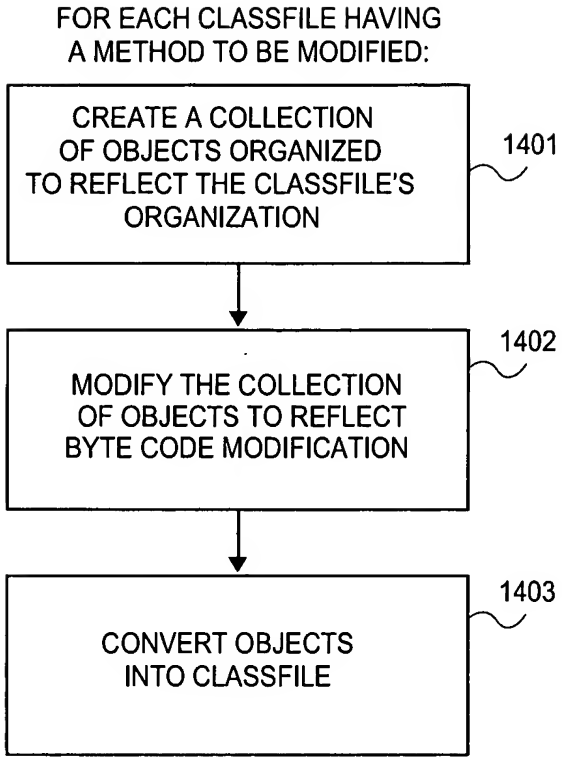

FOR EACH CLASSFILE HAVING
A METHOD TO BE MODIFIED:
CREATE A COLLECTION
OF OBJECTS ORGANIZED
TO REFLECT THE CLASSFILE'S
ORGANIZATION
1401
MODIFY THE COLLECTION
OF OBJECTS TO REFLECT
BYTE CODE MODIFICATION
1402
CONVERT OBJECTS
INTO CLASSFILE
1403

FIG. 14

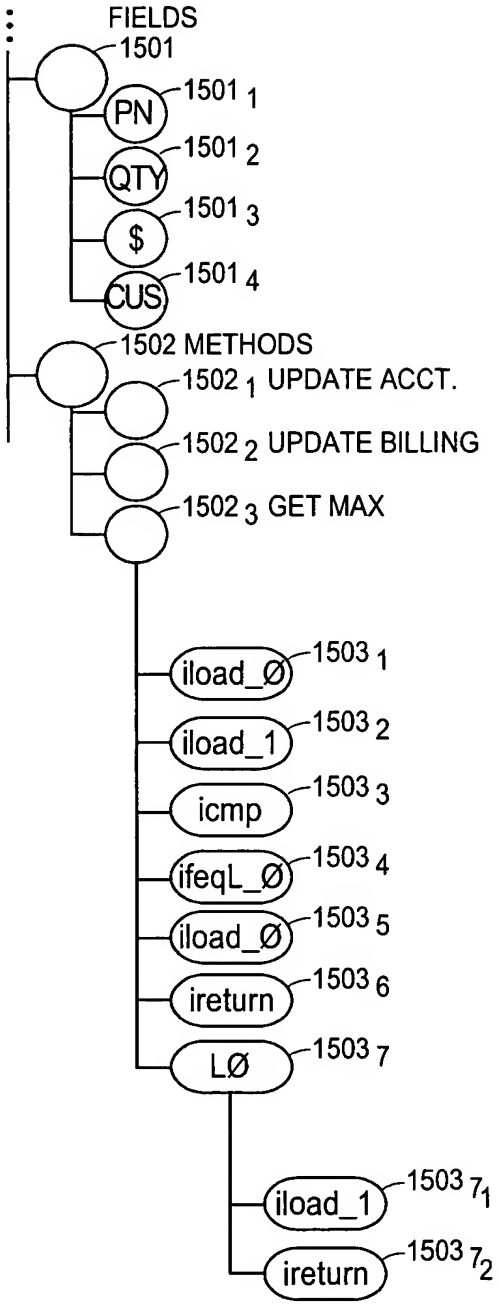


FIG. 15A

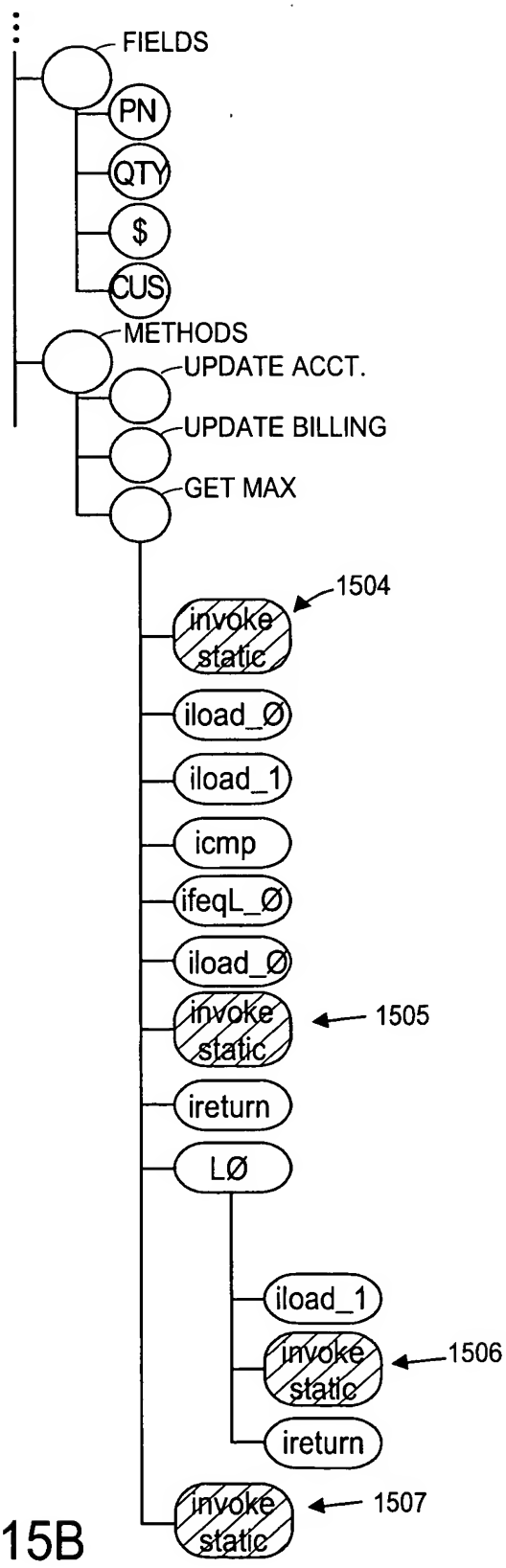


FIG. 15B

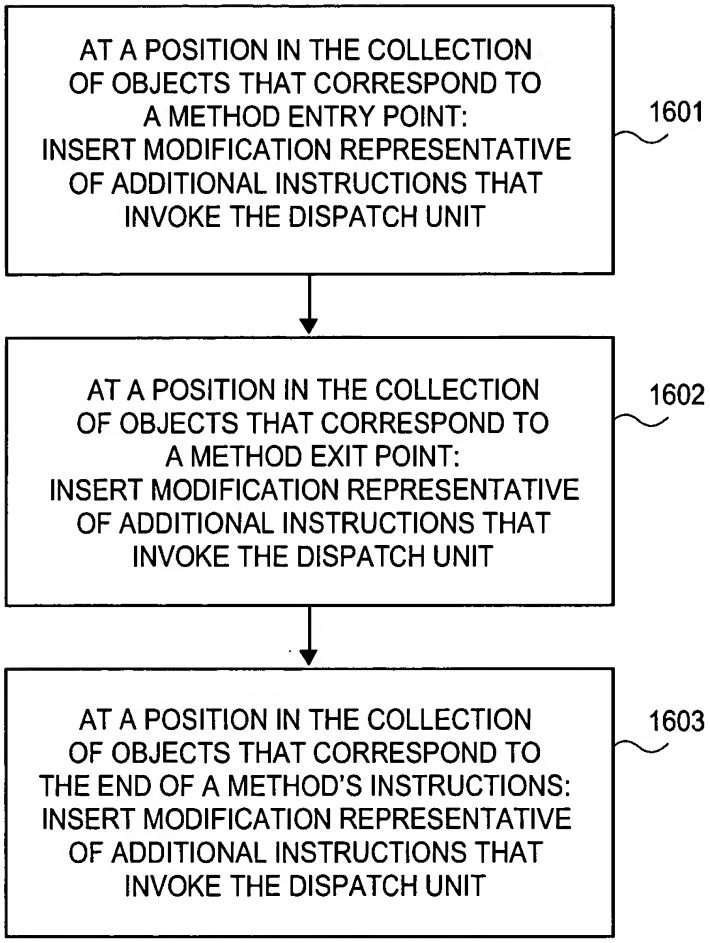

AT A POSITION IN THE COLLECTION OF OBJECTS THAT CORRESPOND TO A METHOD ENTRY POINT: INSERT MODIFICATION REPRESENTATIVE OF ADDITIONAL INSTRUCTIONS THAT INVOKE THE DISPATCH UNIT
1601
AT A POSITION IN THE COLLECTION OF OBJECTS THAT CORRESPOND TO A METHOD EXIT POINT: INSERT MODIFICATION REPRESENTATIVE OF ADDITIONAL INSTRUCTIONS THAT INVOKE THE DISPATCH UNIT
1602
AT A POSITION IN THE COLLECTION OF OBJECTS THAT CORRESPOND TO THE END OF A METHOD'S INSTRUCTIONS: INSERT MODIFICATION REPRESENTATIVE OF ADDITIONAL INSTRUCTIONS THAT INVOKE THE DISPATCH UNIT
1603

FIG. 16

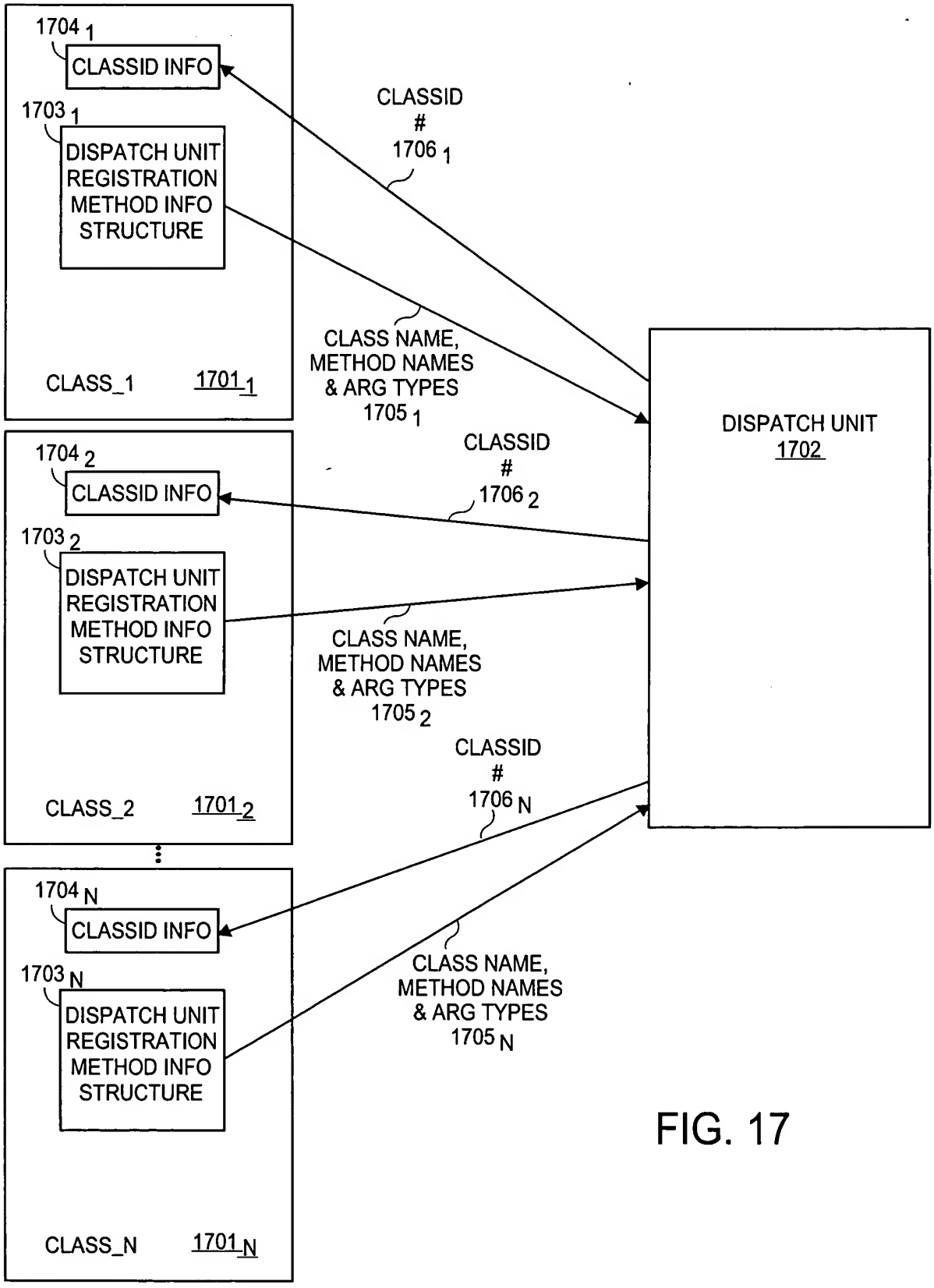

1704 1
CLASSID INFO
1703 1
DISPATCH UNIT REGISTRATION METHOD INFO STRUCTURE
CLASS_1
1701 1
CLASSID # 1706 1
CLASS NAME, METHOD NAMES & ARG TYPES 1705 1
DISPATCH UNIT 1702
1704 2
CLASSID INFO
1703 2
DISPATCH UNIT REGISTRATION METHOD INFO STRUCTURE
CLASS_2
1701 2
CLASSID # 1706 2
CLASS NAME, METHOD NAMES & ARG TYPES 1705 2
1704 N
CLASSID INFO
1703 N
DISPATCH UNIT REGISTRATION METHOD INFO STRUCTURE
CLASS_N
1701 N
CLASSID # 1706 N
CLASS NAME, METHOD NAMES & ARG TYPES 1705 N

FIG. 17

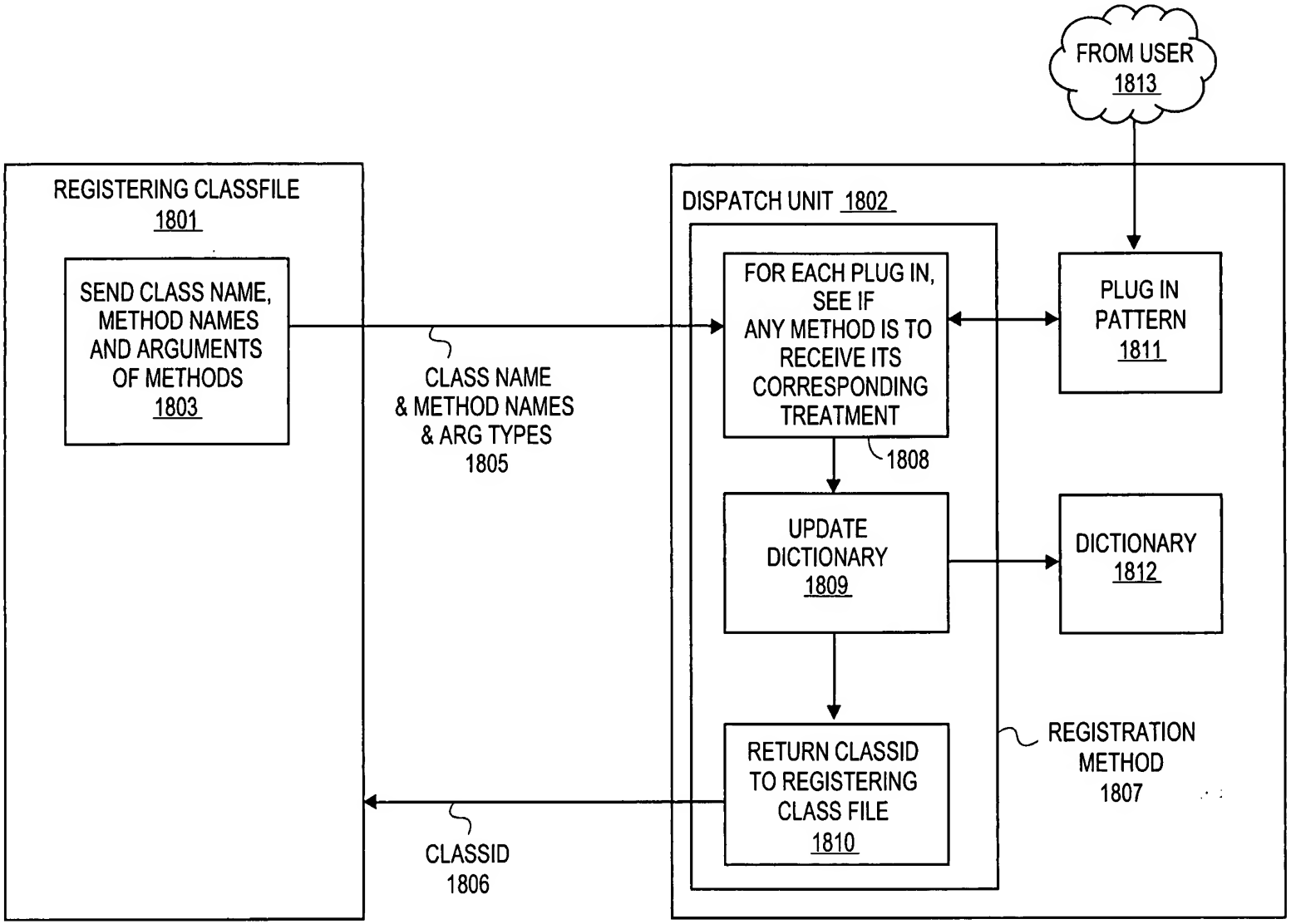

FROM USER
1813
REGISTERING CLASSFILE
1801
SEND CLASS NAME, METHOD NAMES AND ARGUMENTS OF METHODS
1803
CLASS NAME & METHOD NAMES & ARG TYPES
1805
DISPATCH UNIT 1802
FOR EACH PLUG IN, SEE IF ANY METHOD IS TO RECEIVE ITS CORRESPONDING TREATMENT
1808
PLUG IN PATTERN
1811
UPDATE DICTIONARY
1809
DICTIONARY
1812
RETURN CLASSID TO REGISTERING CLASS FILE
1810
REGISTRATION METHOD
1807
CLASSID
1806

FIG. 18

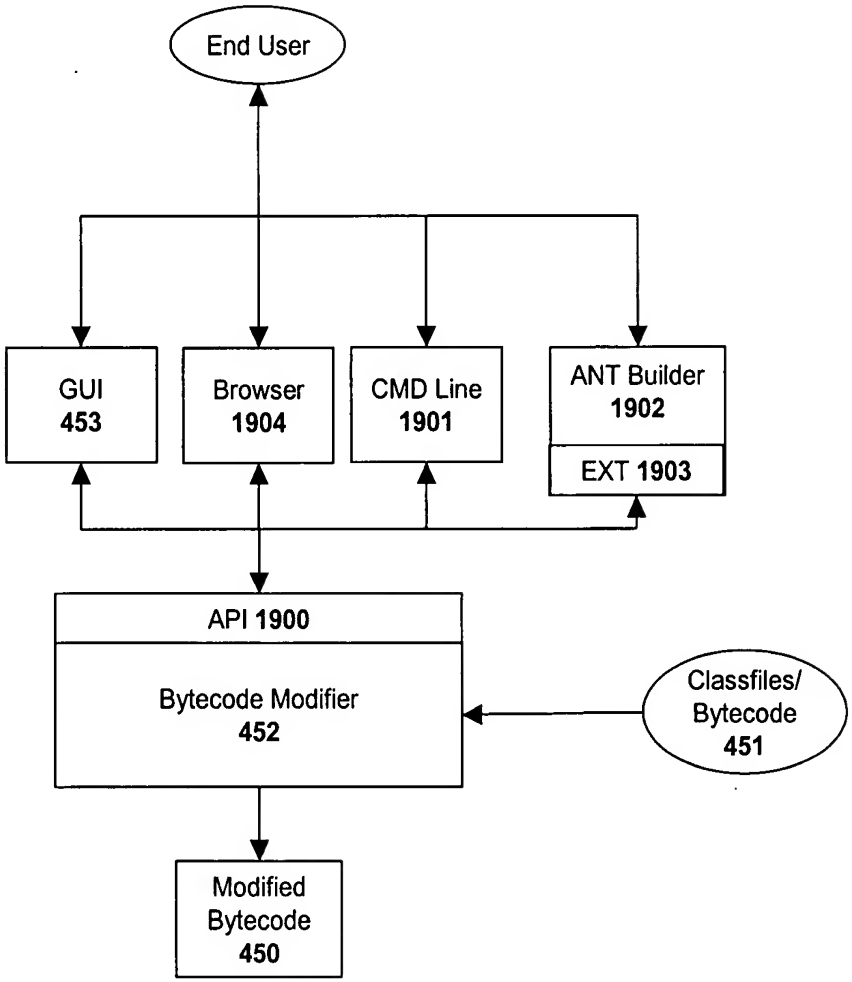

End User
GUI
453
Browser
1904
CMD Line
1901
ANT Builder
1902
EXT 1903
API 1900
Bytecode Modifier
452
Classfiles/
Bytecode
451
Modified
Bytecode
450

FIG. 19A

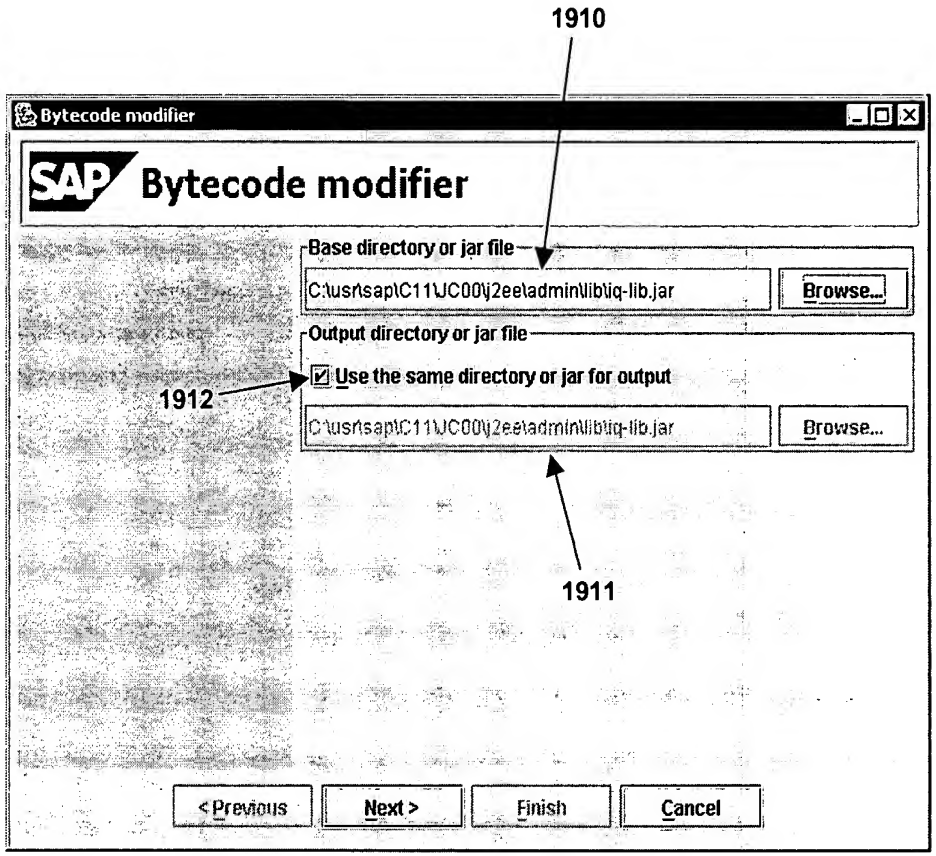

1910
Bytecode modifier
Bytecode modifier
Base directory or jar file
C:\usr\sap\C11\JC00\j2ee\admin\lib\iq-lib.jar
Browse...
Output directory or jar file
Use the same directory or jar for output
1912
C:\usr\sap\C11\JC00\j2ee\admin\lib\iq-lib.jar
Browse...
1911
< Previous
Next >
Finish
Cancel

FIG. 19B

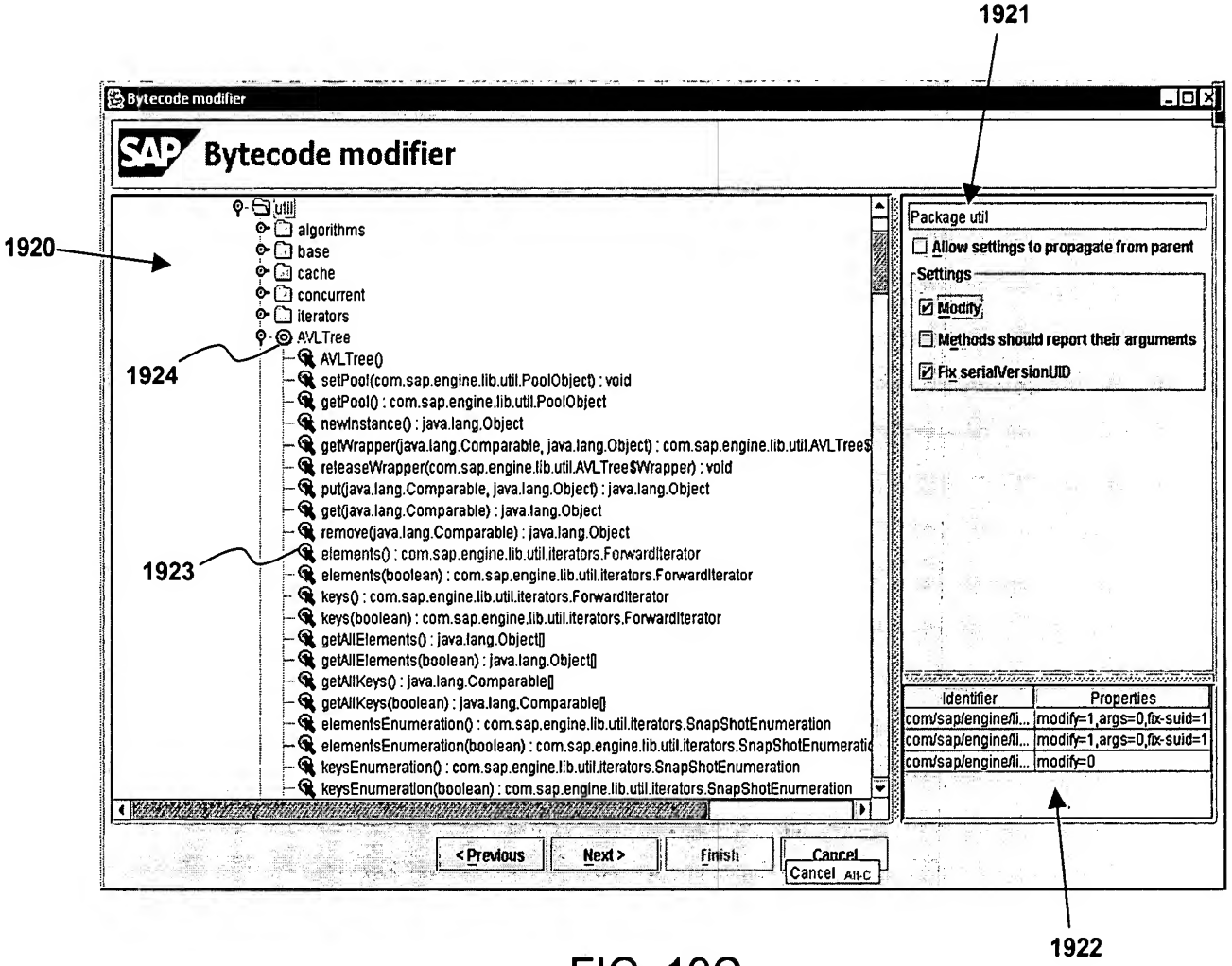

1921
Bytecode modifier
Bytecode modifier
1920
util
algorithms
base
cache
concurrent
iterators
AVLTree
1924
AVLTree()
setPool(com.sap.engine.lib.util.PoolObject) : void
getPool() : com.sap.engine.lib.util.PoolObject
newInstance() : java.lang.Object
getWrapper(java.lang.Comparable, java.lang.Object) : com.sap.engine.lib.util.AVLTree$
releaseWrapper(com.sap.engine.lib.util.AVLTree$Wrapper) : void
put(java.lang.Comparable, java.lang.Object) : java.lang.Object
get(java.lang.Comparable) : java.lang.Object
remove(java.lang.Comparable) : java.lang.Object
1923
elements() : com.sap.engine.lib.util.iterators.ForwardIterator
elements(boolean) : com.sap.engine.lib.util.iterators.ForwardIterator
keys() : com.sap.engine.lib.util.iterators.ForwardIterator
keys(boolean) : com.sap.engine.lib.util.iterators.ForwardIterator
getAllElements() : java.lang.Object[]
getAllElements(boolean) : java.lang.Object[]
getAllKeys() : java.lang.Comparable[]
getAllKeys(boolean) : java.lang.Comparable[]
elementsEnumeration() : com.sap.engine.lib.util.iterators.SnapShotEnumeration
elementsEnumeration(boolean) : com.sap.engine.lib.util.iterators.SnapShotEnumeratio
keysEnumeration() : com.sap.engine.lib.util.iterators.SnapShotEnumeration
keysEnumeration(boolean) : com.sap.engine.lib.util.iterators.SnapShotEnumeration
Package util
Allow settings to propagate from parent
Settings
Modify
Methods should report their arguments
Fix serialVersionUID
Identifier
Properties
com/sap/engine/li...
modify=1,args=0,fix-suid=1
com/sap/engine/li...
modify=1,args=0,fix-suid=1
com/sap/engine/li...
modify=0
< Previous
Next >
Finish
Cancel
Cancel Alt-C
1922

FIG. 19C

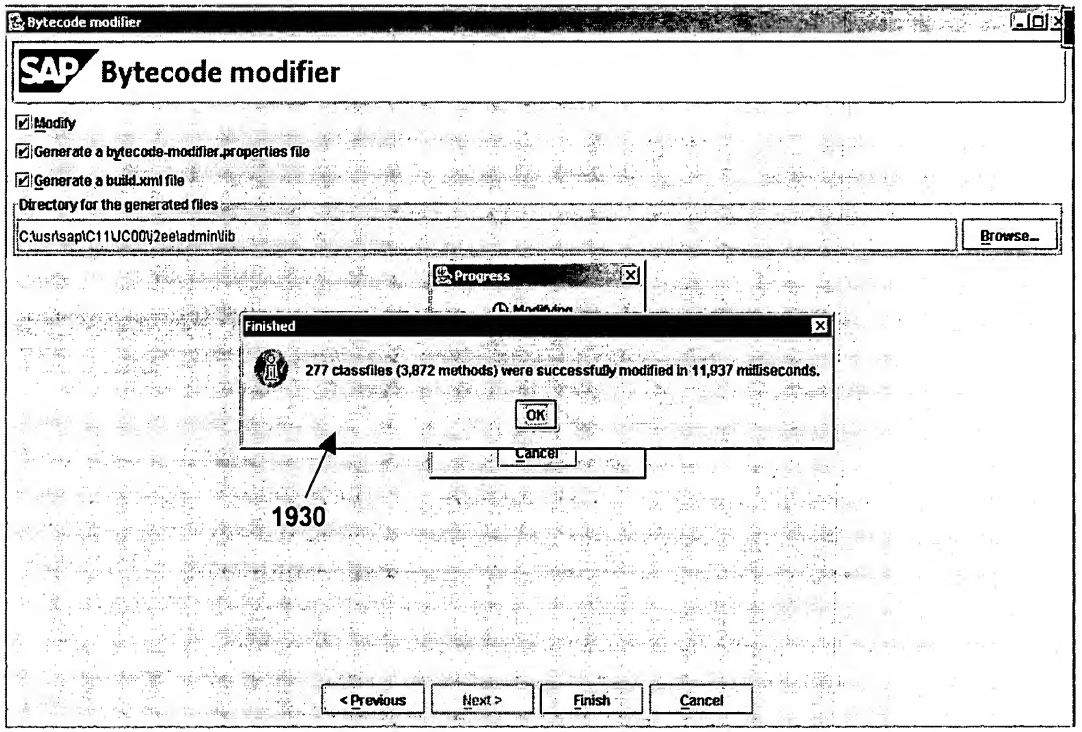
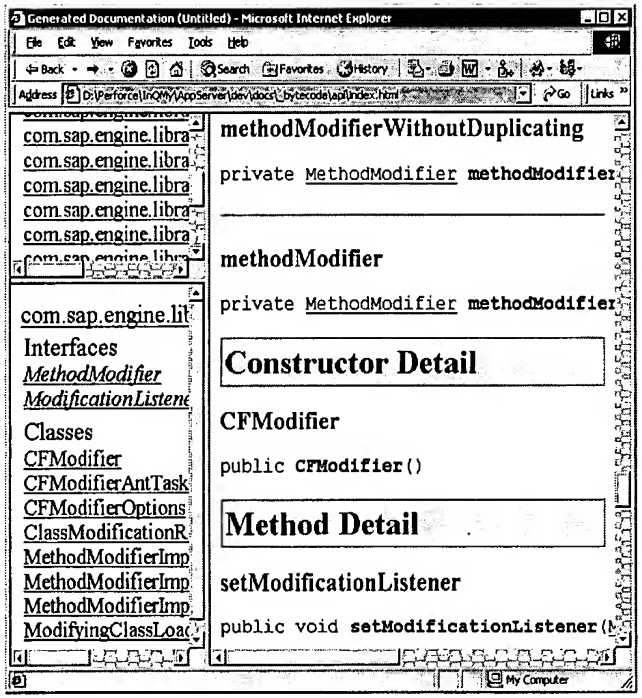

Bytecode modifier
Bytecode modifier
Modify
Generate a bytecode-modifier.properties file
Generate a build.xml file
Directory for the generated files
C:\usr\sap\C11\JC00\j2ee\admin\lib
Browse...
Progress
Finished
277 classfiles (3,872 methods) were successfully modified in 11,937 milliseconds.
OK
Cancel
1930
< Previous
Next >
Finish
Cancel

FIG. 19D



1940

```
// Direct modification of a file
CFModifier modifier = new CFModifier();
modifier.modify("D:/temp/A.class", null);

// Modification in a classloader
Class defineModifiedClass(byte[] data) {
  CFModifier modifier = new CFModifier();
  byte[] data1 = modifier.modify(data);
  return defineClass(data1);
}
```

FIG. 19E

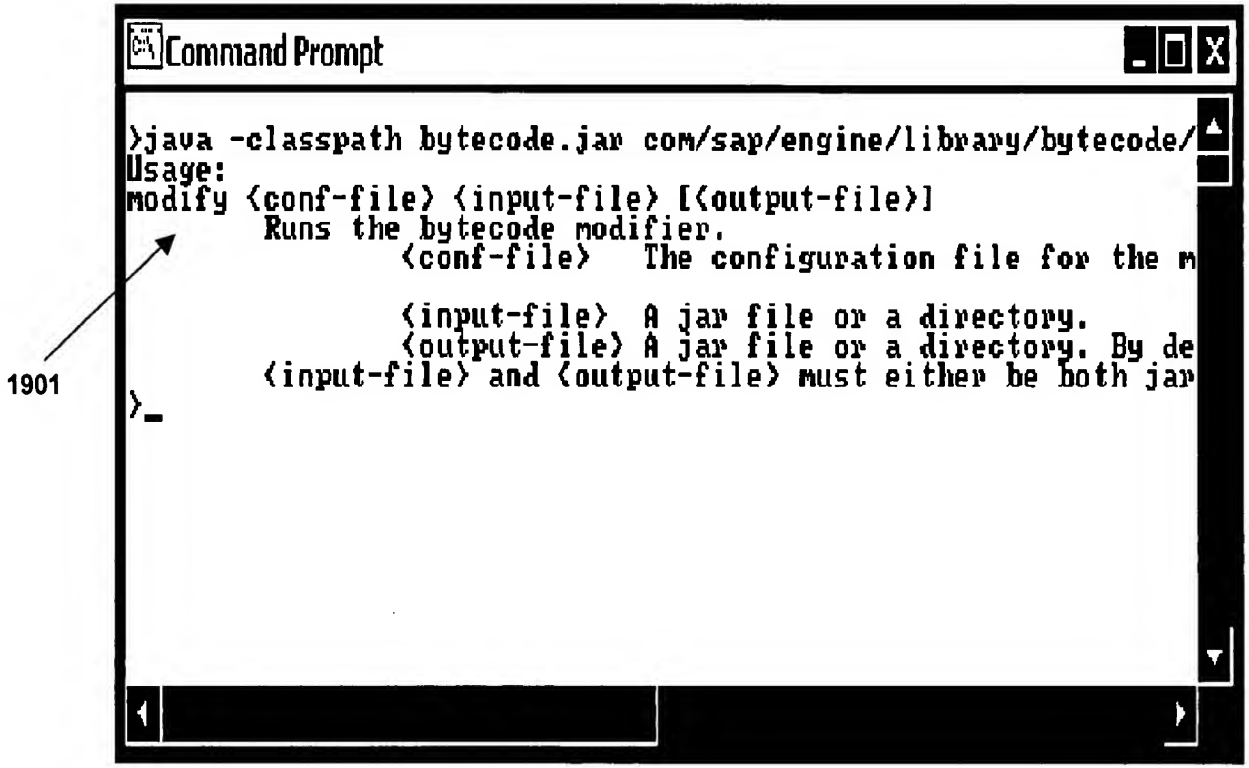

Command Prompt
>java -classpath bytecode.jar com/sap/engine/library/bytecode/
Usage:
modify <conf-file> <input-file> [<output-file>]
Runs the bytecode modifier.
<conf-file> The configuration file for the m
<input-file> A jar file or a directory.
<output-file> A jar file or a directory. By de
<input-file> and <output-file> must either be both jar
>_
1901

FIG. 19F

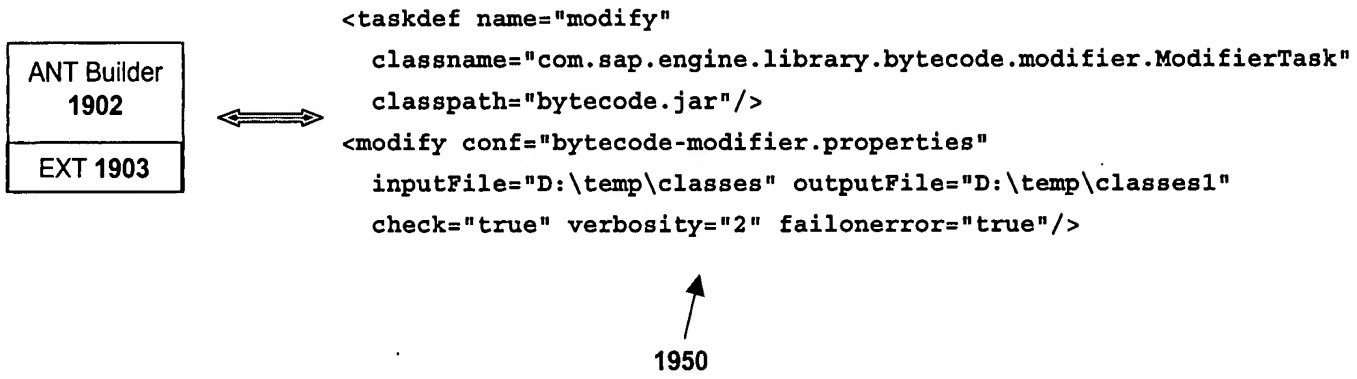

ANT Builder
1902
EXT 1903
<taskdef name="modify"
classname="com.sap.engine.library.bytecode.modifier.ModifierTask"
classpath="bytecode.jar"/>
<modify conf="bytecode-modifier.properties"
inputFile="D:\temp\classes" outputFile="D:\temp\classes1"
check="true" verbosity="2" failonerror="true"/>
1950

FIG. 19G